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Effect of Mineral N on C and N Dynamics of Rice and Wheat Residues under Different Moisture Levels

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Abstract. Crop residue mineralization affects soil carbon (C) and nitrogen (N) dynamics during crop residue management in crop production. C and N mineralization dynamics of rice and wheat residues incorporated with and without mineral N under two moisture conditions were evaluated under laboratory conditions. Mineral N was applied @ 0.015 g/Kg (≈30 Kg/ha), whereas soil moisture was maintained at high (≈ – 15 KPa, near field capacity) and at low (≈ – 500 KPa)moisture levels during course of study. Periodic determinations on CO_2 – C and N mineralized were performed over a period of 120 days. The highest peaks for CO_2 – C occurred during first week of the study which then reduced gradually until it attained an equilibrium. High moisture level enhanced CO_2 – C flux by 14% than low moisture level. Combined application of crop residues and mineral N released 17% more CO_2 – C than crop residue treatments without mineral N.In residue applied treatments, immobilization was 40% higher at high moisture level than that at low moisture level. Application of rice and wheat residues in combination with mineral N caused both immobilizations followed by mineralization phases at both moisture levels. At high moisture level, maximum immobilization occurred during initial 15 days, while at low moisture level it continued till about 30 days. After day15, mineralization started which continued to increase during remaining period of study at high moisture and at low moisture mineralization initiated from day 60 onward. Mineralization in rice residue was faster than that in wheat residues. Immobilization of N continued progressively in residue alone treated soils at both moisture levels during study period. In residue treated soils, increase in soil moisture increased soil organic carbon (SOC) and soil water stable aggregates (WSA) significantly by 14% and 55% over control respectively.Combined application of crop residues and mineral N increased SOC by 43% and WSA by 59%. This study indicated that incorporation of crop residues along with addition of mineral N in the presence of optimum moisture promoted its faster decomposition with a quicker mineral N release, more organic matter build up and soil structure improvement than crop residues incorporated without mineral N.

Keywords: C and N mineralization, rice and wheat residues, soil moisture

Introduction

Soil organic carbon (C) and nitrogen (N) are the key indicators of soil quality and fertility in arable lands (Moreno-Cornejo, 2014). Crop residue management has a marked influence on carbon (C) and nitrogen (N) turn over in agro-ecosystems. Long term decline in soil fertility and quality is commonly associated with partial or complete removal or burning of above ground biomass (Kong *et al*., 2005; Lal, 2004). The crop residues incorporation is suggested as a potential means of sustaining soil fertility and productivity over the long-term (Singh and Rengel, 2007; Carter, 2002; Rasmussen and Parton, 1994) by improving physical and biological conditions of the soil (Ali and Nabi, 2016; Nyborg *et al*., 1995). Therefore, crop residues incorporation is encouraged inorder to recycle nutrients to soil and increase soil organic matter content (Ali and Nabi, 2016; Partey *et al*., 2014; Kone *et al*., 2010).

The rice-wheat cropping system in Pakistan is one of the major cropping systems practiced on an estimated area of 2.2 million/ha which produces (GOP, 2015). About 10–14 mg/ha crop residues are produced in Rice and wheat cropping system (Samra *et al*., 2003). In recent past whole crop biomass were removed from fileds during manual harvesting but recently with the advent of mechanized harvesting, only plant tops with grains are removed, while a major part of biomass is left in the fields as crop residues. Since left over residues interfere with tillage and seeding operations for the next crop, farmers often prefer to burn in situ, causing huge losses of soil organic matter (SOM) and nutrients,

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increasing C emissions, resulting in air pollution and reducing soil microbial activity (Kumar and Goh, 2000; Nguyen *et al*., 1994).

Decomposition of straw incorporated in soil is governed by many factors such as moisture, temperature and nutrient addition. Optimum soil moisture and mineral nitrogen input are the most important factors affecting straw decomposition. Soil moisture greatly enhance straw decomposition and CO_2 flux (Tulina *et al*., 2009; Kruse *et al*., 2004; Lomander *et al*., 1998) or reduce it (Iqbal *et al*., 2009; Li *et al*., 2006). Nitrogen availability controls the kinetics of decomposition of crop residues, particularly those with high C/N ratio such as cereals, when the N requirements of the soil decomposers are not fulfilled by the residue or soil N contents (Recous *et al*., 1995). Many researchers have reported that the addition of supplemental N has been successfully used to enhances decomposition of straw by lowering the C:N ratios of soils in which straw has been incorporated (Abro *et al*., 2011; Chen *et al*. 2007; Potthoff *et al*., 2005).

Since residue decomposition rate determine the duration of net N immobilization and net N mineralization which consequently influence the net supply of N from residue to the ensuing crop and also on carbon storage in soil, whereas residue quality and environmental condition-sdictate decomposition rate. Therefore, the study of decomposition dynamics of crop residues and factors affecting, it has a key role in crop residue management in field.Consequently, a good knowledge of the C and N dynamics in soil and underlying causes is required to improve the synchronization of N supply with demand (Kumar and Goh, 2000).

Therefore,a study was conducted to evaluate C and N dynamics of rice and wheat residue with and without mineral nitrogen input under different moisture conditions at laboratory levels. This information will help in understanding residue management practices in long term field trials.

Materials and Methods

Soil characteristics and crop residues. The surface (0 -15 cm) soil was collected from the rice-wheat area of Sadhoke, 5 km south east of GT road, Kamonke, district Gujranwala, Punjab, Pakistan. The soil belonged to Gujranwala soil series (moderately well drained, non-calcareous, silty clay loam, hyperthermic Udic Haplustalfs) based on Soil Survey Report, 1965. The collected soil was brought to LRRI, NARC. Soil was air dried,visible crop residue and pebbles were removed and sieved through a 2 mm sieve. The texture of soil was silty clay loam with 8.2 pH, 0.15 dS/m EC, 20 g/Kg $CaCO_3$, 2.3 g/Kg organic C, 8.2 mg/Kg mineral N, 2.8 mg/Kg ABDTPA extractable P and 125 mg/Kg of K. The rice and wheat residues were collected from the farmer's field after the harvest of crops. The crop residues were oven dried at 70°C and chopped properly (0.5-1.0 cm pieces). Residues were analyzed for organic C by wet digestion (Nelson and Sommers, 1982) and total N (Jackson, 1982). Organic C in rice and wheat residues was 50.21 and 53.84 % respectively, whereas total N was 0.73 and 0.46 % respectively. The C/N ratio of rice residue was 69, while that of wheat was 116.

Experimental design and treatments. An incubation experiment was laid out in two factor factorial complete randomized design (CRD). Two moisture levels -15 kP_a as High Moisture (HM) level and −500 kP_a as Low Moisture (LM) level each maintained with 6 residue treatments: control (soil only, CS); soil + mineral N (SMN); soil+wheat residue (SWR); soil+ rice residue (SRR); soil+ wheat residue + mineral N (SWR+N) and soil+rice residue + mineral N (SRR+N) each in four replications.

The prepared soil was split into two equal halves and placed on separate plastic sheet. One half was moistened to (≈ -15 kP_a) and the other half moistened to (≈ -500 kPa)by sprinkling distilled water followed by gentle mixing. Soil water retention capacity at ≈ -15 kP_a and -500 kP_a was determined by filter paper method (Deka *et al*., 1996). The moistened soil was sealed in plastic bags and allowed to cure for 72 h in a dark cold room to ensure uniform distribution of moisture throughout the soil and to attain moisture equilibrium. Both crop residues were applied @ 5.0 mg/g soil (~ 9 mg/ha) and mineral N @ 0.15 mg/g (~30 Kg/ha). Urea fertilizer was used as mineral N source. Two separate sets, one for CO_2 release and another for mineral nitrogen release were established. Both sets were incubated in a growth chamber maintained at 25ºC temperature for 120 days.

Carbon mineralization. Moistened soil (200 g soil on dry weight basis) was taken in 1.0 L plastic jars. Rice and wheat residues and mineral N were poured into jar and thoroughly mixed with soil. A vial containing 10 mL of 1.0 M NaOH were placed in jars to trap the evolved CO_2. Jars were covered with their lids and then lid and the jar interface was sealed with paper tape. An absolute control treatment (empty jar) was also maintained as blank. Alkali traps were removed at 1, 3, 5, 10, 15, 20, 30, 45, 60, 75, 90, 105 and 120 d (days) after incubation began and CO_2 absorbed was analyzed by titration with 0.5 M HCl in the presence of $BaCl_2$ (Anderson, 1982). During and after titration, jars were left open for 3 h to fully replenish with oxygen. The soil moisture content of the soil residue mixture was monitored throughout the study period by weighing and maintained by adding distilled water as needed periodically. At end of the experiment, soil in each jar was analyzed for soil organic carbon (Nelson and Sommers, 1982) and aggregate stability (Kemper and Rosenau, 1986). Soil stable aggregates (%) > 250 µm (macro-aggregates) were determined by using wet sieving apparatus of EijkelkampAgrisearch Equipment by the Netherland.

N mineralization. Moistened soil (500 g soil on dry weight basis) was taken in 0.5 L plastic jars. Rice and wheat residues and mineral N were thoroughly mixed as for the carbon mineralization study. Jars were covered with plastic sheets (with small vents for air exchange) to reduce evaporation from soil. The soil moisture content of the soil residue mixture was monitored throughout the study period by weighing and maintained by adding distilled water as needed periodically. On day 0, 15, 30, 45, 60, 75, 90, 105 and 120 after incubation, 20 g of soil from each jar was destructively sampled and analyzed for N mineralization. At each time samples so collected were air dried, sieved through 1 mm sieve and analyzed for mineral N (Keeney and Nelson, 1982).

Calculation

CO_2 emission during the interval (CO_2-C) was calculated as eq. 01 (Chen *et al*., 2009):

$$CO_2\text{-C(mg/Kg soil was added)} = \frac{(V_b - V_s) \times N \times 12 \times 1000}{Ws \times 44} \quad ..(eq.01)$$

where:

V_b and V_s = the volumes of HCl used in blank and sample respectively; N = the normality of HCl; W_s = the weight of soil used per Jar.

Daily $CO_2 - C$ flux was calculated as:

$$\text{Daily } CO_2 - C \text{ flux (mg/Kg soil/day)} = \frac{CO_2\text{–C (mg/Kg soil)}}{t_i} \quad ..(eq.\ 02)$$

where:

ti = the time interval between each sampling day

Total CO_2–C flux was calculated as:

$$\text{Total } CO_2 - C \text{ (mg/Kg soil)} = \sum_{120}^{1} CO_2 - C \text{ (mg/Kg soil)} ..... (eq.03)$$

Mineral N measured incontrolat each sampling day was subtracted from that of wheat residue (WR) and rice residue (RR), while mineral N measured in N applied treatment (SMN) was subtracted from that of SWR+SMN and SRR+SMN to determine the net amount of mineralized N from or immobilized N by crop residues.

Statistical analysis. Collected data on total CO_2-C, SOC and soil stable aggregates were subjected to analysis of variance (ANOVA) under two factors factorial in Completely Randomized Design (CRD) (Gomez and Gomez, 1984). Least significant differences at $P \leq 0.05$ was used to separate the means. At each sampling time means and standard errors were also computed for making comparisons. For statistical analysis, computer software "MSTAT-C" was used, while graphs were drawn in MS-Excel 2016.

Results and Discussion

Daily $CO_2 - C$ flux. Effect of moisture levels and residue treatments on daily $CO_2 - C$ flux are presented in Fig. 1.All treatments indicated a similar pattern of daily $CO_2 - C$ flux at both moisture levels. There was a very rapid C mineralization at the onset of the experiment during initial 6 days, which then levelled off gradually and ultimately became stable after day 30. Beyond 30 days it continued to decrease but at much slower pace. Similar results have also been observed by Ali and Nabi (2016). The highest peaks for CO_2–C in initial days of the incubation period was attributed to the microbial respiration and decomposition of easily decomposable organic compounds in crop residues during this time (Curtin *et al*., 1998; Krieft *et al*., 1987) which induced microbial growth initially and decreased afterwards due to the exhaustion of those substances (Kachroo *et al*., 2006; Khalil *et al*., 2005; Mishra *et al*., 2001). Trinsoutrot *et al*. (2000),Martens (2000) and Stevenson (1986) observed that easily decomposable compounds like carbohydrate and amino acid content contribute to the majority of CO_2 efflux from soil rather than the soil phenolic acid content.

In the beginning of the experiment, there were large variationsin daily $CO_2 - C$ flux among the treatments. However, these differences were narrowed down by the day 30 of the study. Overall $CO_2 - C$ flux from crop residues with mineral N input were higher throughout the experimental period. Regardless of the residue type or moisture level, all treatments produced highest daily $CO_2 - C$ flux at day 4 which then subsided sharply till day 10 and then further decreased gradually till day 30. Maximum daily $CO_2 - C$ flux observed from rice and wheat residues combined with mineral N input (SRR+N and SWR+N) at day 4 was 20.30 and 19.52 mg/Kg/d respectively, which was significantly higher than all other treatments at all incubation periods up to the day 28. Increase in the decomposition rate with increasing N availability may be attributed to increase in the population of more efficient decomposers in the microbial community having greater N requirements (Agren *et al*., 2001). These findings were consistent with Moran *et al*. (2005) and Lueken *et al*. (1962). Almost similar trend in maize straw with mineral N was also observed by (Abro *et al*., 2011; Chen *et al*., 2007; Potthoff *et al*., 2005).

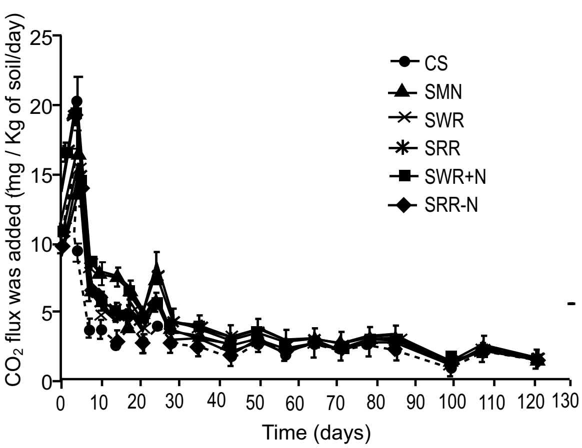

Fig. 1. Daily CO_2 flux from rice and wheat residue with and without mineral N.
where:

CS= control soil; SMN= soil + mineral nitrogen; SWR= soil + wheat residue; SRR= soil+ rice residue; SWR+N= soil + wheat residue with mineral nitrogen; SRR+N= soil+rice residue with mineral nitrogen. Vertical bars represent standard error of means (n=4)

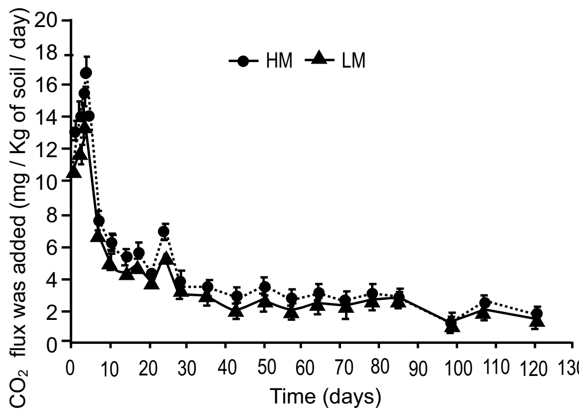

Fig. 2. Daily CO_2 flux from rice and wheat residue at different soil moisture levels.
where:

HM= is the high moisture; LM= the low moisture. Vertical bars represent standard error of means (n=4)

Moisture levels significantly affected daily $CO_2 - C$ flux (Fig. 2). Increase in moisture hastened the evolution of daily $CO_2 - C$ during decomposition of organic residues. Maximum daily $CO_2 - C$ flux (16.7 mg/Kg/d) was observed at day 4 for high moisture level which was significantly higher than low moisture level (14.2 mg/Kg/d). During the rapid C mineralization phase (first week of incubation period), daily $CO_2 - C$ flux was significantly higher for high moisture level as compared to low moisture at all duration of incubation period but was markedly higher with no significant differences afterwards. Increase in moisture enhanced the oxidation process of crop residues which consequently enhanced their decomposition process. Similar results were also reported by Tulina *et al*. (2009) and Hossain and Puteh (2013).

Total CO_2–C flux. Total $CO_2 - C$ emission for 120 days was significantly ($P < 0.0001$) affected by soil moisture and treatments. But the interaction between moisture levels and crop residues treatments was non-significant. Higher moisture level significantly enhanced $CO_2 - C$ flux by 14% (Fig. 3) than in low moisture level. This significant increase in $CO_2 - C$ flux due to high moisture was in all treatments except control. Moisture enhances the oxidation process of crop residues which consequently enhances their decomposition process. Similarly, Zhang *et al*. (2008) and Chen *et al*. (2014) also reported increase in CO_2 flux with increase in moisture content from the straw amended soil as compared to the non-amended soil.

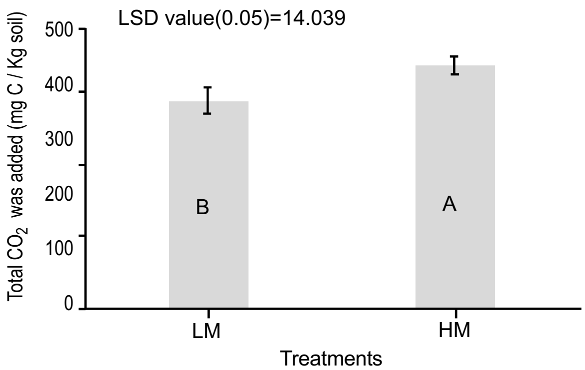

Fig. 3. Total CO_2 flux from rice and wheat residues at different moisture levels.
where:

HM= high moisture; LM= low moisture. Vertical bars represent standard error of means (n=4). Letters represent mean comparison.

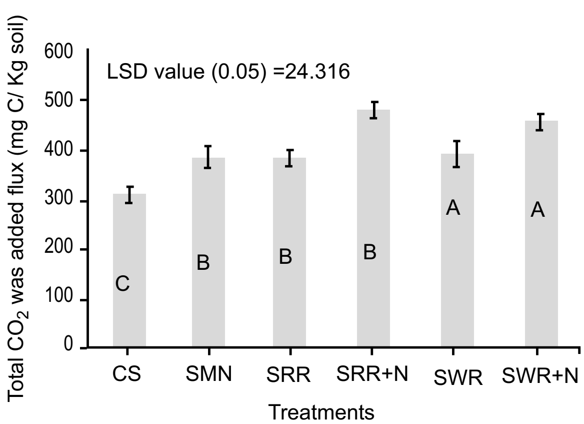

Fig. 4. Total CO_2 flux from rice and wheat residues with and without mineral N.
where:

CS= control soil; SMN= soil + mineral nitrogen; SWR= soil + wheat residue; SRR= soil+ rice residue; SWR+N= soil + wheat residue with mineral nitrogen; SRR+N= soil+rice residue with mineral nitrogen. Vertical bars represent standard error of means (n=4). Letters represent mean comparison

Regardless of the moisture levels, treatments significantly differed in total $CO_2 - C$ flux (Fig. 4). Mineral N and crop residue addition to soil significantly enhanced total $CO_2{-}C$ flux. Significantly highest $CO_2{-}C$ flux was recorded from crop residue with mineral N treatments (SWR+N and SRR+N) compared to all other treatments followed by crop residue treatments without mineral N (SWR and SRR) which were significantly higher from control (CS), while at par with mineral N treatment (SMN). Addition of crop residue to soil acts as a substrate for soil microbes which results in increased microbial activities and consequently increased CO_2 evolution. Mineral N input also significantly enhanced $CO_2 - C$ flux in control, soil (CS) as well as in the crop residue amended soil. Addition of mineral N (SMN) released 19% higher $CO_2 - C$ than control whereas mineral N input + crop residues (SRR+SMN and SWR+SMN) enhanced $CO_2 - C$ flux by 17% over crop residue treatments without mineral N (SRR and SWR). The enhancement of $CO_2 – C$ release from control soil due to addition of mineral N showed accelerated soil organic matter decomposition. These findings are in agreement with (Muhammad *et al*., 2011: Moran *et al*., 2005) who reported a significant increase in CO_2 emission with N fertilizer input to crop residue amended soil. Increase in the decomposition rate with increasing N availability may be attributed to increase in the population of more efficient decomposers in the microbial community having greater N requirements (Agren *et al*., 2001).

Nitrogen mineralization. Considerable differences in the pattern of N mineralization/immobilization in soil were observed when exposed to different moisture levels and rice and wheat residue application with and without mineral N (Fig. 5).

Incorporation of crop residue (wheat and rice)without mineral N (SRR and SWR)significantly reduced inorganic N content of soil (immobilized)at both moisture levels and this N immobilization persisted throughout the incubation period. This immobilization was faster during initial 15 days of incubation more and in high moisture than in low moisture level. At high moisture it attained a steady state after 15 days, while in low moisture immobilization further continued progressively during the study period. Also, there were no marked differences in N immobilization between rice and wheat residues applied without mineral N.Several researchers (Qian and Schoenau, 2002; Nicolardot *et al*., 2001; Van Kessel *et al*., 2000) found that residues with high C/N ratio exhibit immobilization. Trinsoutrot *et al*. (2000)

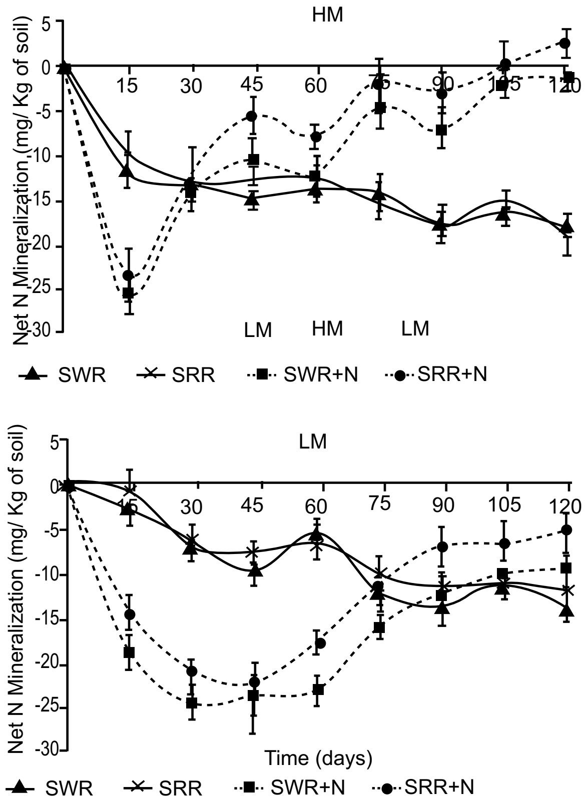

Fig. 5. N mineralization (NO_3-N + NH_4-N) release from rice and wheat residues with and without mineral N at different moisture levels.
where:

HM= high moisture; LM= low moisture; CS= control soil; SMN= soil + mineral nitrogen; SWR= soil + wheat residue; SRR= soil+ rice residue; SWR+N= soil + wheat residue with mineral nitrogen; SRR+N= soil + rice residue with mineral nitrogen. Vertical bars represent standard error of means (n=4)

related dynamics of soil mineral N mainly to the C/N ratios of the crop residues applied to soil.Immobilization of mineral N by rice and wheat residues with high C/N ratio could be due to the large demand for N by micro-organisms proliferating rapidly in response to the availability of easily decomposable carbon compounds.

Incorporation of rice and wheat residues in combination with mineral N (SRR+N and SWR+N) gave rise to both immobilization and mineralization phases of soil mineral N. At both moisture levels, SRR+N and SWR+N immobilized a maximum amount of about 26 and 24 mg N/Kg soil respectively. But at high moisture level, maximum immobilization occurred during initial 15 days, while at low moisture level it continued 30 to 45 days, SRR+SMN and SWR+SMN resulted in 29 and 19% increase in immobilization at high moisture level and 26 and 17% increase in immobilization at low moisture level as compared to SRR and SWR respectively.Similar findings were also reported in white lupin residues (Doel *et al*., 1990) and carrot leaves (De Neve and Hofman, 2002). At high moisture, N mineralization started after 15 days, while at low moisture, N mineralization started after 45 days. The mineralization rate was faster at high moisture level than at low moisture level. In rice residue treatments, mineralization was higher than in wheat residue treatments. The presence of mineralization phase showed that urea hydrolyzed to mineral N and this increasing N availability increased the population of more efficient decomposers in the microbial community that have more N requirements (Agren *et al*., 2001) which enhanced the crop residue mineralization.

Soil moisture pronouncedly affected soil mineral N immobilization / mineralization pattern. Within 120 days of incubation period, SRR and SWR treatments immobilized 40% more N at high moisture level than that at low moisture level. Whereas, SRR+SMN and SWR+SMN within 15 days immobilized about 25% and 38% more soil mineral N at high moisture level than at low moisture level, while in 120 days (at the termination of experiment), SRR+SMN and SWR+SMN re-mineralized about 105 and 89% of immobilized N at high moisture level and 64 and 49% at low moisture level respectively. These results showed that increasing moisture affected both N immobilization and mineralization processes in soil. This may be attributed to the more moisture availability for microbial activities at high moisture level. Optimum moisture availability is an essential requirement for higher microbial growth since low soil moisture can retard microbial activity by reducing intracellular water potential of microbes (Stark Firestone, 1995; Csonka, 1989) and diffusion of soluble substrates (Schjønning *et al*., 2003; Griffin, 1981).

Comparing rice and wheat residues, no prominent differences in N immobilization and mineralization were observed when applied without mineral N at both moisture levels but when applied in integration with mineral N, wheat residue markedly immobilized higher amount of mineral N with lower remineralization ability than rice residues at both moisture levels.

In rice-wheat area of Pakistan, the time window between wheat harvesting and rice transplanting is about 60 days which provides enough time for residues to decompose and mineralize N if the crop residues are incorporated immediately after wheat harvesting. But the time window between rice harvesting and wheat sowing is short (20–25 days) thus incorporation must be done as early as possible after rice harvesting and additional dose of mineral N (~25 N Kg/ha) should also be applied to avoid N deficiency during germination and early growth. A light irrigation must also be applied just after residue incorporation to promote rapid mineralization of the residues. Crop residue incorporation will enhance soil organic matter and will improve soil structure.

Soil organic carbon (SOC). Soil organic carbon (SOC) contents were significantly affected by soil moisturelevels ($P = 0.0132$) and treatments ($P < 0.0001$). However, interaction between soil moisture and treatments was non-significant. Increase in soil moisture content increased SOC content significantly (Fig. 6). Increase in soil moisture content from low to high increased SOC by 14%. Since soil moisture enhance soil microbial activities and crop residue decomposition which releases organic compounds in soil which are retained by soil matrix resulting an increase in SOC content.

Regardless of the moisture levels, only the integrated application of rice and wheat residue with mineral N (SRR+N and SWR+N) significantly increased SOC over control soil by 43%. While no-significant differences in SOC was observed for alone application of crop residues (SRR, SWR) and mineral N over control (Fig. 7). Crop residues without mineral N (SRR and SWR) increased SOC over control soil by 8%. Similar results were also reported by Poirier *et al*. (2013) and Esther *et al*. (2013) who observed increase in SOC with the incorporation of corn and wheat straw.SRR+N and SWR+N increased SOC content by 41% and 34% over SRR and SWR treatments. Our results showed that integrated use of mineral fertilizer with organic amendments are more effective in enhancing SOC content as compared to the sole application of organic residues. In a five-season experiment in a guar–wheat rotation in a sandy clay loam soil, Rezig *et al*. (2013) reported significantly higher SOC content from integrated application of crop residues than sole application of crop residues.

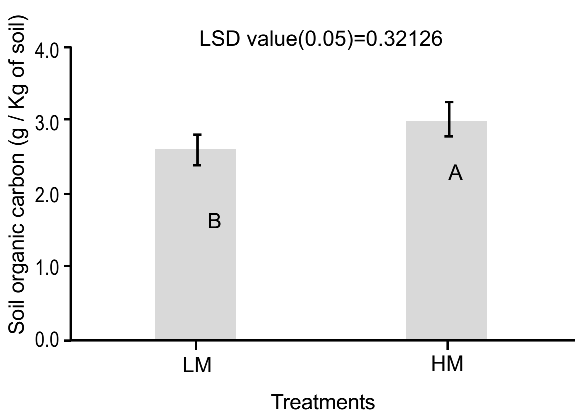

Fig. 6. Soil organic carbon under rice and wheat residues at different moisture levels. where:

HM= high moisture; LM= low moisture. Vertical bars represent standard error of means (n=4). Treatments followed by different letters are significantly different at $P < 0.05$.Letters represent mean comparison.

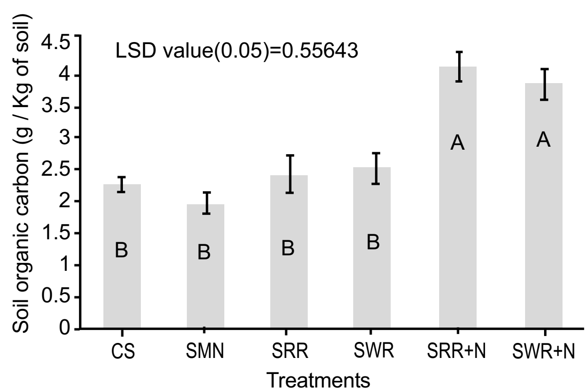

Fig. 7. Soil organic carbon under rice and wheat residues with and without mineral N. where:

CS= control soil; SMN= soil + mineral nitrogen; SWR= soil + wheat residue; SRR= soil+ rice residue; SWR+N= soil + wheat residue with mineral nitrogen; SRR+N, soil + rice residue with mineral nitrogen. Vertical bars represent standard error of means (n=4). Treatments followed by different letters are significantly different at $P < 0.05$.

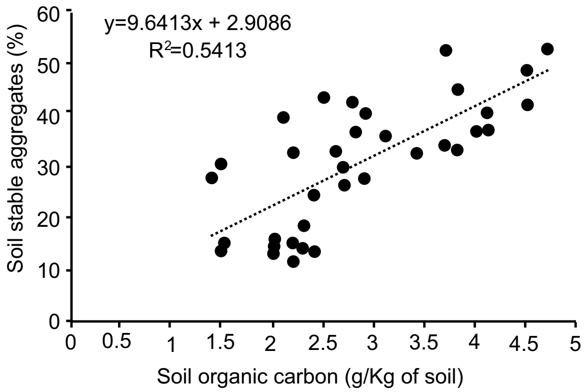

Fig. 8. Relation between soil organic carbon and soil water stable aggregates

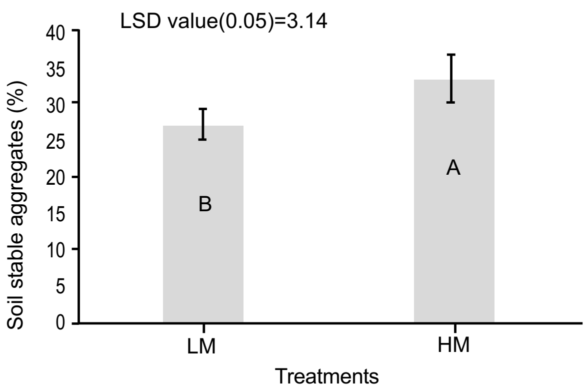

Fig. 9. Soil water stable aggregatesunder rice and wheat residues at bars represent standard error of means (n=4). Treatments different moisture levels.
where:

HM= high moisture; LM= low moisture. Vertical followed by different letters are significantly different at P < 0.05.

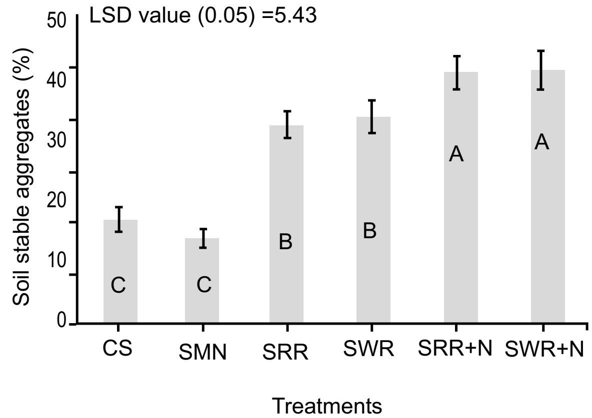

Fig. 10. Soil water stable aggregatesunder rice and wheat residues with and without mineral N.
where:

CS, control soil; SMN, soil + mineral nitrogen; SWR, soil + wheat residue; SRR, soil+ rice residue; SWR+N, soil + wheat residue with mineral nitrogen; SRR+N, soil + rice residue with mineral nitrogen. Vertical bars represent standard error of means (n=4). Treatments followed by different letters are significantly different at P < 0.05.

Soil water stable aggregates (WSA). Similar trend for soil water stable aggregates (WSA) under different soil moisture levels and treatments was observed as that for SOC content. Because asignificantly good correlation (r = 0.837; P = 0.000) of WSA with SOC was observed. This significant correlation may be attributed to the physical protection of SOC inside the soil aggregates (Tisdall and Oades, 1982). Regression analysis (Fig. 8) also showed that the increase in WSA due to soil organic carbon was 54% (R^2 = 0.54) which was statistically significant ($P < 0.001$). Similarly Stengel *et al*. (1984) observed a similar regression equation (12.75 + 11.75 SOC (%); $R^2 = 0.61$, $P < 0.001$) for soil stable aggregates SOC.

Soil moisture levels (P = 0.0003) and treatments (P < 0.0001) significantly affected WSA. Increase in soil moisture content significantly increased WSA (Fig. 9). Increase in WSA at high moisture content was 19% over low moisture content. High WSA due to high moisture content may be due to the high soil organic carbon content at high moisture level which act as a cementing agent for aggregate formation and stabilization (Chaney and Swift, 1984). Regardless of the soil moisture levels, rice and wheat residues both alone and together with mineral N, increased soil aggregate stability significantly (Fig. 10). Rice and wheat residues with mineral N increased the amount of WSA by 59% and without mineral N by 48% over control soil, (Chivenge *et al*. 2011; Marten 2000, Aggarwal *et al*. 1995; Sarkar and Rathore, 1992) have also shown improved structure with organic residues applied to soil by increasing soil aggregate stability. Allison (1968) attributed the increase in soil aggregate stability to the release of cementing agents responsible for aggregation by soil micro-organisms upon organic residue decomposition.

Conclusion

Mechanized harvesting in rice wheat cropping system leaves behind about 4–5 mg/ha of crop residues which creates hindrance in seedbed preparation of succeeding crop. For a quick seedbed preparation, farmers burn these residues which creates soil health and environmental problems. Our observations showed that rice residue has faster C mineralization rates than wheat residues. Further, the mineralization rates were faster when residues were subjected to both mineral N and high moisture. Without mineral N addition, residues application caused immobilization of soil N up to the end of the experimental period (120 days), the application of mineral N and high moisture significantly enhanced its decomposition and initiated faster mineralization. Incorporated rice and wheat residues increased soil organic carbon by 18%, while soil stable macro-aggregates by 50% over un-amended soil.

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Conflict of Interest. The authors declare no conflict of interest.

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