RELATIVE CONTRIBUTION OF CROP RESIDUE BOUND-N TO IRRIGATED RICE AND CARBON STORAGE IN A SUBTROPICAL SOIL

M. I. Khalil[1,2], M. A. Haque[1], M. A. Sattar[1], U. Schmidhalter[2]
[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture
P.O. Box 4, Mymensingh 2200, Bangladesh. khalilmi@bttb.net.bd
[2]Chair of Plant Nutrition, Department of Plant Sciences,
Technical University Munich, D-85350 Freising, Germany

ABSTRACT

A field experiment was carried out in a non-calcareous sandy loam soil of subtropics using crop residue and root biomass of preceding rainfed rice to study the soil organic carbon (SOC) storage and nutrient uptake by succeeding irrigated rice. Decomposition of incorporated biomass was rapid initially and the residue-amended plots showed higher peaks for CO_2 fluxes. N transformations were faster during the initial period, indicating dominant microbial activities in the 0-2.5 cm soil depth. Fluctuations of mineral N content, where NO_3^- level was smaller, revealed the influence of irrigation events, split N applications and crop uptake. Crop residue of 20 cm height along with root biomass and inorganic fertilizers depicted significantly the highest grain yield of rice (8 t ha^{-1}) and a maximum apparent added N recovery, ANR (62.7%). Incorporation of additional crop residue (40 cm height) showed a poor ANR (1.3%) probably due to N immobilization. Relative contribution of root biomass to grain yield and N recovery was small (9 and 7.6%, respectively). At harvest, SOC raised with the increasing amount of added crop biomass over initial levels, ranging from 3.8 to 28.3%. Results suggest that the root/crop biomass could contribute to SOC and nutrients build-up in the soil.
Keywords: *Rice residue, N recovery, organic matter build-up, subtropics.*

INTRODUCTION

Soil organic matter plays an important role in nutrient cycling, water retention and overall soil quality. Loss of it leads to soil erosion, reduction in soil tilth and decline of soil productivity. Type of crops, cropping systems, tillage practices and fertilizers management factors are largely influenced by the retention of organic matter (OM) in soils (Powlson, 1996). Addition of inputs regulates microbial activities, which in turn mediate the C turnover and nutrient cycling. Study on C and N mineralization potential and the factors influencing the processes is an important global focus for C sequestration and environmental preservation (Lal et al., 2003). It is also for the efficient prediction of the need for N fertilization from organic sources. In Bangladesh, a large amount of nutrients as biomass is taken out of the crop fields for fuel/animal feed. Its use along with inorganic fertilizers can enhance the added nutrient use efficiency of crops and help in maintaining soil productivity. Research works using organic amendments (Zaman, 2002) and ^{15}N-enriched wheat residue (Rahman et al., 2001) towards yield potentials and nutrient uptake by rice as well as their relative contribution to OM build-up were reported to be inadequate. It is of greater interest for estimating the nutrient supplying capacity of the soil and C sequestration potential in agricultural soils of the tropics. Thus, a long-term field experiment has been established to study the contribution of crop residue/biomass fractions to C storage and nutrient uptake by a rice-rice cropping system with or without application of inorganic fertilizers.

MATERIALS AND METHODS

An experiment was carried out at a farmer's field in 2003 having sandy loam in texture, well drained and belongs to the Sonatala series (Aeric Haplaquepts). Organic C (0.99%), pH (5.0), N (0.08%) and CEC (10.2 $cmol_c\ kg^{-1}$) of the soil were low. The experiment with irrigated rice (cv. BINA Dhan 6) was set up in a RCB design. The treatments comprised of: T_0 - Bare; T_1 - No inputs; T_2 - Recommended fertilizers; T_3 - T_2 + root debris; T_4 - T_3 + rice residue (20 cm height); and T_5 - T_3 + rice residue (40 cm height). Inorganic fertilizers at a rate of 128, 141, 100 and 2.6 kg ha^{-1} were applied as TSP, MP, gypsum and ZnO, respectively along with 1/3 urea of the total amount (245 kg ha^{-1}) during final land preparation. The remaining 2/3 urea in two equal splits were applied at 25 and 54 days after transplanting (DAT). Crop residue and root biomass of the previous rice crop was removed or added as per treatments. Estimated root biomass, crop residue for 20, and 40 cm height was 890, 1990 and 2560 kg ha^{-1}. The corresponding amount of N, P and K was 3.0, 1.2, 3.7; 8.6, 2.6, 23.0 and 9.9, 2.6, 27.5 kg ha^{-1}. The biomass was incorporated 7 days before transplanting. Irrigation water was applied at 3-4 days after recession of surface water and at a threadlike crack to 3 cm standing water during early and later growth stages, respectively. Grain and straw yields ware recorded. At 10 days interval, CO_2 evolution was measured following alkaline trap (1M KOH) and soils were sampled after fertilization onwards at a depth of 0-2.5, 2.5-7.5 and 7.5-15 cm to determine mineral and total N, pH and organic C as well as total N for plant samples. Statistical analyses were performed using SAS 1999-2000 Inc.

RESULTS AND DISCUSSION

Carbon Mineralization

Evolution of CO_2 differed insignificantly between treatments during the initial period (Fig. 1a), attributing to the contribution of native SOC remained as labile conditions. A faster decomposition was observed till 40 DAT with a maximum efflux of 5333 mg CO_2 m^{-2} day^{-1} in the plots receiving inorganic fertilizers, root debris and crop residue of 40 cm height (T_5). Afterwards, the fluxes became small with intermittent fluctuations and it was higher from the plots receiving crop residues than from the plots under bare and getting no residues/inorganic fertilizers. Increased CO_2 emissions were depicted in the crop residue-treated plots during the later periods of crop growth as well. It may be ascribed to the drying processes that caused an increasing mineralization of labile C and leaf senescence to some extent during aerobiosis. The alternate wetting and drying processes did probably not limit the decomposition of added organic materials.

Nitrogen Transformations

Accumulation of NH_4^+-N was faster during the initial period in the 0-2.5 cm soil depth followed by some oxidation of it depending on soil pH and frequency of irrigations (data not shown). Some immobilization of N might occur in the plots receiving crop residues. The bare plots showed net N mineralization (5.7-7.3 mg N kg^{-1} soil) followed by the plots receiving no inputs (Fig. 1b). In the 0-2.5 cm soil depth, net N mineralization was negative in all treatment plots and degree of which depended on the decreasing amount of biomass received, indicating remineralization of N immobilized due to the added biomass. In the lower depths, a small net N mineralization was observed, ranging from 0.1-1.2 mg N kg^{-1} soil. The net N mineralization was generally associated with the presence of NH_4^+-N at the end of study that enhanced with increasing amount of crop residue and was presumably related to CO_2 effluxes.

Accumulation of NO_3—N was rapid in the biomass-amended plots and T_5 treatment showed the highest one (19.4 mg N kg^{-1} soil). In the 0-2.5 cm soil depth, net nitrification was larger in T_5 (6.3 mg N kg^{-1} soil) than in the other treatments (1.8-4.4 mg N kg^{-1} soil). Net nitrification, except for bare plots, was found to be the highest in the lower depths. This indicates some probable movement or accumulation of NO_3—N in the lower depths. A relative contribution of crop residue to N build-up was spectacular. However, denitrification during anaerobiosis could not be ignored. Surekha et al. (2003) also reported an increased soil N by incorporating crop residues. They observed a significant influence of added OM on N mineralization but the process was slow, which might take the major parts for N increase.

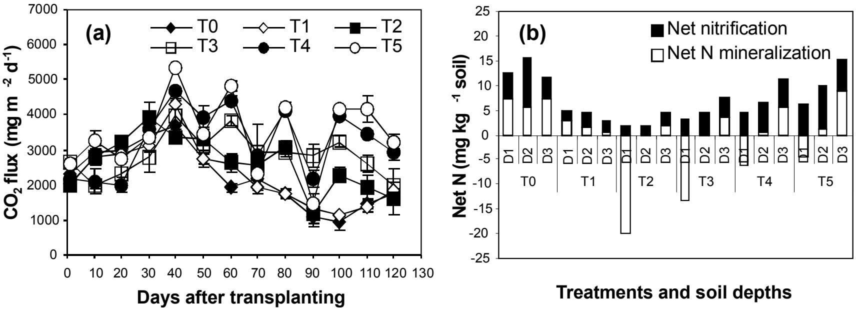

Figure 1. Evolution of CO2 out of the crop field (a) and net N mineralization and nitrification (b) [T0- Bare; T1- No inputs; T2 - Inorganic fertilizers; T3 - T2 + Root biomass, T4 - T3 + Rice residues (20 cm height); and T5 - T3 + Rice residues (40 cm height); D1: 0-2.5 cm, D2: 2.5-7.5 cm and D3: 7.5-15.0 cm]. The vertical bars indicate standard error.

Status of soil organic C

Fig. 2a shows a maximum increase of soil organic carbon (SOC) in T_5 treatment (1.28%). Its content decreased with the soil depths and increased with the amount of applied crop biomass (Paustian et al., 1998; Surekha et al., 2003). There were minor roles of T_1 and T_2 treatments. In terms of OM build-up, contribution of root biomass was significant but it was larger from the applied crop residue. The increase in organic C ranged from 3.8-6.7, 5.2-11.7 and 17.0-28.3% due to root biomass, crop residues of 20 and 40 cm height along with root biomass, respectively at various soil depths. It might be short-term as some C loss might occur during fallow period. Similarly, Surekha et al. (2003) found an increase in SOC content by 20-27% with the added crop residues having wider C/N ratios after five seasons of experimentations.

Yields and N recovery by the rice

Application of inorganic fertilizers and root debris/crop residue significantly influenced the yields of irrigated rice (Fig. 2b) Grain yield was the highest (8.0 t ha^{-1}) in T_4 treatment and it was significantly lower in T_5 treatment (7.0 t ha^{-1}) though receiving 20 cm additional crop residue. It may be attributed to N immobilization occurred during the early period that limited the crop growth, and varied insignificantly with T_2 and T_3 treatments. The grain yield increased up to two-fold due to application of inorganic fertilizers as compared with T_1 receiving no fertilizers. Relative contribution of root biomass alone or along with crop residue (20 cm) to grain yield was 9 and 26%, respectively. Relative recovery of the added N showed similar trends and a maximum of 62.7% was depicted for T_4 treatment (Fig. 2b). The yield increased due to the incorporated biomass was probably related to the amount and availability of nutrients added to the soil. Surekha et al. (2003) also did not find an increased yield of irrigated rice with a larger amount of crop residues during the initial two seasons. However, they reported an increased dry season yield of rice by 1.0 to 1.2 t ha^{-1} over time associated with the improvement of soil properties and nutrient supplying capacity.

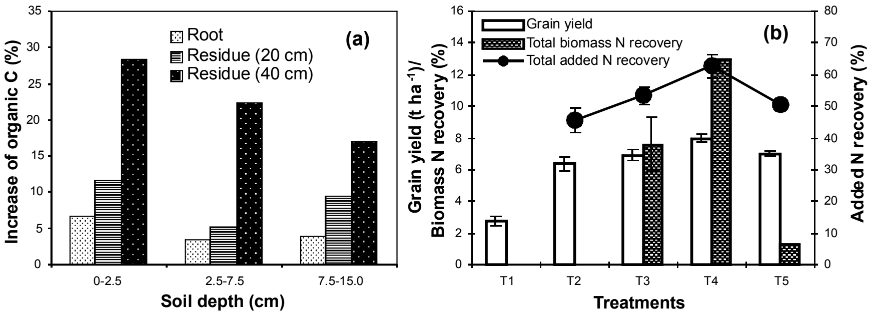

Figure 2. *Percent relative contribution of added root/crop biomass to OM build-up (a), grain yield and N recovery (b) of the irrigated rice [T0 - Bare; T1- No inputs; T2 - Inorganic fertilizers; T3 - T2 + Root biomass, T4 - T3 + Rice residue (20 cm height); and T5 - T3 + Rice residue (40 cm height)]. The vertical bars indicate standard error.*

CONCLUSIONS

Decomposition of added crop residue depended mostly on irrigation events and it was rapid during the initial period. N mineralization and nitrification were presumably limited by irrigation frequency and crop N uptake. Organic matter build-up and N accumulation was observed and N immobilization might occur depending on the amount of added crop biomass, regulating the yield potential and N recovery of the rice. Results suggest that the crop biomass either above or belowground could contribute largely to soil fertility maintenance.

Acknowledgements. We gratefully acknowledge the Danish International Development Agency, Ministry of Agriculture, Government of Bangladesh and Alexander von Humboldt Foundation, Germany. Thanks to Mr. M. A. Wahab Mia, Mrs. K. Nahar and Mr. J. Alam for their technical assistance.

REFERENCES

Lal, R., Follett, R.F., Kimble, J.M. 2003. Achieving soil carbon sequestration in the United States: Challenge to the policy makers. Soil Sci., 168: 827-845.

Paustian, K., Elliott, E.T., Carter, M.R. 1998. Tillage and crop management impacts on soil C storage: Use of long-term experimental data. Soil Till. Res., 47: vii-xii.

Powlson, D.S., Smith, P., Smith, J.W. 1996. Evaluation of soil organic matter models using long-term data sets. In: *NATO ASI Series I: Global Environmental Change 38,* Springer, Berlin, 429p.

Rahman, S.M., Haque, M.E., Ahmed, S., Khalil, M.I., Mia, M.A.W. 2001. Studies of organic matter turnover and nutrient build-up in a Bangladesh soil for sustainable agriculture. In: *Report presented in the Final RCM of the Joint FAO/IAEA Divisions*, Kuala Lumpur, Malaysia, 37 p.

Surekha, K., Kumari, A.P.P., Reddy, M.N., Satyanarayana, K., Cruz, P.C.S. 2003. Crop residue management to sustain soil fertility and irrigated rice yields. Nutr. Cycl. Agroecosys., 67: 145-154.

Zaman, S.K. 2002. Integration of fertilizer and manure for sustainable soil fertility and productivity in rice-rice cropping system. Ph.D. Thesis. Department of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh, 223p.