Geophysical Research Abstracts
Vol. 15, EGU2013-1082-2, 2013
EGU General Assembly 2013

Influence of biotic and abiotic processes on the immobilization and distribution of applied N in fertilized paddy soils

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Poor fertilizer-N use efficiency is characteristic of irrigated rice agro-ecosystems with recoveries ranging from 40–60% of applied N. This has been largely attributed to a greater degree of N immobilization and important losses of applied fertilizer-N as a consequence of the alternating soil redox conditions to which paddy soils are subjected during the cropping season. This work aims at providing a better understanding of biotic and abiotic processes controlling N immobilization in these soils, necessary to improve fertilizer-N management and the sustainability of rice agro-ecosystems.

To evaluate the relative contribution of biotic and abiotic processes affecting N immobilization, a typical paddy soil was incubated for 30 days under (i) sterile or non-sterile anoxic conditions, (ii) with or without the addition of rice straw. Gamma radiation was utilized to sterilize the soils without affecting soil properties, while anaerobic conditions were ensured by incubating the soils under water saturated conditions. Enriched ammonium-^{15}N was applied to evaluate the immobilization of fertilizer-N while the distribution of immobilized N among soil fractions was assessed by combining aggregate size and organic matter density fractionation.

Results have evidenced a rapid immobilization of $\sim$40% of applied N in both sterilized and non-sterilized treatments. Most of this N ($\sim$87%) was associated with the finest soil fractions ($<20\mu$m) present in both macro- and microaggregates. Interlayer NH_4^+ fixation was probably responsible for this rapid immobilization since XRD analyses showed that the soil used had a clay fraction dominated by vermiculite and illite. However, sterilized soils had more fertilizer-N associated with the finer fractions in microaggregates and less with macroaggregates with respect to non-sterilized soils. In fact, aggregate stability was significantly compromised in sterilized soils, thus influencing the distribution of immobilized N. Addition of straw to non-sterilized soils enhanced N immobilization with more fertilizer-N associated with the light organic matter fraction (LF) compared to soils not receiving straw. Biotic immobilization of applied N and incorporation into amide-N during the decomposition of added straw was further confirmed by ^{15}N-CPMAS-NMR spectra of the LF. Sterilized soils receiving straw also showed a slight increase in isotopic enrichment of the LF. However, SEM analyses suggested that the presence of clay particles on the surface of vegetal fragments could be responsible for the transfer of fertilizer-N onto the LF under sterile conditions.

This work highlights the importance of abiotic processes in controlling N availability in fertilized lowland paddy soils. In particular, interlayer NH_4^+ fixation is expected to directly influence N availability in temperate paddy soils having a mineralogical composition rich in 2:1 clay minerals. On the other hand, biotic processes may not only lead to the immobilization of significant amounts of applied N particularly in the presence of labile organic matter, but may also have an indirect effect on abiotic processes by contributing to aggregate stability.