ClimaRice Technical Brief # 4 -2011

Algal carbon sequestration in rice soil eco system

CLIMARICE II: "Sustaining rice production in a changing climate"

A. Lakshmanan and V. Geethalakshmi

(TNAU, Coimbatore, India)

This Technical brief is a short summary of the results obtained from the field experiments conducted at Anbhil Dharmalingam Agricultural College and Research Institute, Trichy to study the algal succession in rice soil besides quantifying the biomass generation potential of different Cyanobacterial species, namely *Nostoc, Anabaena*, *Westiellopsis* and *Plectonema*, isolated from Cauvery basin as a part of the ClimaRice project during the summer season 2010. Higher *Nostoc* abundance coincided with lower of other two genera. *Anabaena* was the first cyanobacterial species to develop in field two weeks after transplantation of rice. Many rice-field soils not only contain a high density of cyanobacteria, but possess visually obvious growths of cyanobacteria at (or floating above) the surface, during most part of the growth stages. Cyanobacteria which multiplies easily in rice field ecosystem has great potential as biofertilizer, also it could be employed for sequestering atmospheric carbon in paddy soils.

Introduction

The CO_2 level in the atmosphere, which has been stabilized for 100, 000 years has been rising after the industrial revolution, to a present level of 360 ppm. Geological predictions are that it may reach to a level of 480 ppm by 2050. While agriculture stands to be greatly affected by projected climate change, it has also been a major source of greenhouse gases to the atmosphere and contributes to climate change. Clearing and management of land for food and livestock production over the past century was responsible for cumulative carbon emissions of about 150 GT C, compared to 300 GT C from fossil fuels. At present, agriculture and associated land use changes emit about a quarter of the carbon dioxide (through deforestation and soil organic carbon depletion, machine and fertilizer use), half of the methane (via livestock and rice cultivation), and three-fourths of the nitrous oxide (through fertilizer applications and manure management).

Modifying current management of agricultural systems could therefore greatly help to mitigate global anthropogenic emissions. Many see such activities in the coming decades as new forms of environmental services to be provided to society by farmers, who in turn could additionally increase their income by selling carbon-emission credits to other carbon-emitting sectors.

Sequestration of atmospheric carbon

Possible mitigation approaches in agriculture concentrate on either (or both) of two key components: (1) Sequestration of atmospheric C in agricultural soils, resulting in increased soil organic carbon (SOC) pools; and (2) Reduction of greenhouse gas emissions to the atmosphere from agricultural operations. An important difference among the two options above is that soil carbon sequestration is ultimately finite: positive manipulations in soil management will tend to increase the equilibrium soil carbon pool by increasing C inputs into the soil or by slowing decay rates of soil organic matter, but SOC accumulation will not proceed above the resulting new storage point. By contrast, management changes that reduce carbon fluxes from agricultural operations can last indefinitely, as long as the new management system is sustainable in both energy and ecological terms.

Efforts to improve soil quality and raise SOC levels can be grouped into two sets of practices: crop management and conservation tillage. Both practices evolved as means to enhance sustainability and resilience of agricultural systems, rather than with SOC sequestration in mind. They include so-called ‘‘best practice’’ agricultural techniques, such as use of cover crops and/or nitrogen fixers in rotation cycles; judicious use of fertilizers and organic amendments; soil water management improvements to irrigation and drainage; and improved varieties with high biomass production. In general, the direct benefits of carbon sequestration in reduced tillage systems are limited in time, typically 20–40 years, while those arising from reduced C emissions will last as long as the relative management changes are maintained. Therefore, even when such flux reductions appear small compared to total anthropogenic emissions, they may contribute substantially to mitigate sectoral emissions.

Cyanobacteria as CO2 sinks

Various solutions have been proposed to mitigate the greenhouse effect of CO2 emissions. One of the options currently being explored is the use of cyanobacteria as CO2 sinks. Cyanobacteria have been identified as eco-friendly natural nitrogen fixers in the rice field ecosystem. The utilization of cyanobacteria (Blue green algae) as biofertilizer for rice in supplementing nitrogen is highly promising as the rice field ecosystem provides congenial environment for this self supporting diazotroph. Recently, it has been reported that growing Cyanobacteria in rice fields results in sequestering carbon. Cyanobacteria are attractive candidates in this respect as they are fast growing and easier to manipulate in open ponds. They possess an essential biophysical mechanism (carbon concentrating mechanism, CCM), which concentrates CO2 at the site of photosynthetic carboxylation.

Photo: Blue green algal mat in paddy rhizosphere

In this respect the carbon concentrating mechanism (CCM) in cyanobacteria is similar to that found in C4 land plants. This enables them to maintain high rates of CO2 fixation, and also grow under low CO2 [Badger and Price, 2003].

The pioneering studies of Kaplan *et al*. using *Anabaena variabilis*, demonstrated that cyanobacteria were capable of accumulating inorganic carbon, to such an extent that intracellular concentration could be 1000 folds more than the external environment. Since then DIC (Dissolved Inorganic Carbon) accumulation has been demonstrated in many cyanobacterial strains e.g. *Cocochloris peniocystis*, *Anacystis nidulans* ,*Chlorogloeopsis sp.*, *Nostoc calcicola* etc. Cyanobacteria are excellent model systems which can provide the biotechnologist with novel genes and biomolecules having diverse uses in agriculture, industry and environmental sustainability. These systems also hold promise as efficient contraptions for harnessing greenhouse gases such as CO2 and methane.

Algal succession in Rice soil

Experiments were carried out at Agricultural College and Research institute, Trichy, TN, India to study the algal succession in rice soil besides quantifying the biomass generation potential of different cyanobacterial species isolated from Cauvery basin. The cyanobacterial isolates were belonging to the genera *Nostoc, Anabaena, Westiellopsis* and *Plectonema* and composite inoculum of these cultures were inoculated @ 4Kg per acre. The three main heterocystous genera (*Anabaena*, *Westiellopsis, Nostoc*) responded differently to levels of irradiation.

Higher abundance of *Nostoc* coincided with lower abundance of the other two genera. *Anabaena* was the first cyanobacterial species to develop in field two weeks after transplantation of rice. Kannaiyan (1990) reported that nitrogen fixing forms namely *Scytonema*, *Aulosira*, *Nostoc*, *Aphanotheca*, *Oscillatoria*, *Plectonema* were dominant during tillering phase of rice crop. *Gleotrichia* and *Rivularia* were reported to occur during panicle initiation and flowering phase of rice. Many rice-field soils not only contain a high density of cyanobacteria, but possess visually obvious growths of cyanobacteria at (or floating above) the surface, during most part of the growth stages. Some of the common rice field cyanobacteria are *Anabaena*, *Aulosira*, *Calothrix*, *Gleotrichia*, *Cylindrospermum*, *Nostoc*, *Fischerella*, *Scytonema*, *Tolypothrix* and *Wollea* (Rai *et al*., 2000). In adopting a rational approach for the use and management of natural resources in sustainable agriculture, the biofertilizers hold vast potential. Biofertilizers are major components of sustainable farming and the biological nitrogen fixation (BNF) is a fascinating biological phenomenon studied extensively to provide low cost nitrogen and improve crop productivity. The utilization of cyanobacteria as a biofertilizer for rice is highly promising as the rice field ecosystem provides congenial environment for this self supporting diazotroph.

Besides nitrogen fixation, these photosynthetic algal systems can also be employed for sequestering atmospheric carbon in paddy soils.

Photo: Blue green algal blooms in a Climafarmer field, at Trichy

References

Kannaiyan, S. 1990. Biotechnology of biofertilizer for rice. Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu India, pp: 212.

Kaplan, A., Schwarz, R., Lieman-Herwitz, J, and Reinhold, L. 1994. Physiological and molecular studies on the response of Cyanobacteria to changes in the ambient inorganic carbon concentration. In: The molecular biology of Cyanobacteria (Bryant DA ed), Kluwer Academic Publishers, Dordrecht, The Netherlands, pp: 469–485.

Badger, M. R., and Price, G. D. 2003. CO2 concentrating mechanism in cyanobacteria: molecular components, their diversity and evolution. *J Exp Bot*. 54:609–622.

Rai, L.C., Kumar, H.D. Mohn, F.H, and Soeder, C.J. 2000. Services of algae to the environment. *J. Microbiol. Biotechnol.*, 10: 119-136.

ClimaRice II Project (2009-2011)

ClimaRice II is an integrated project that aims to test and validate climate change adaptation techniques related to rice production, in close co-operation with farmers and local agencies in two study areas in the Cauvery River Basin, Tamil Nadu, and Krishna River Basin, Andhra Pradesh, in India.

The overall goal is to contribute to the regional and national adaptation strategies to sustain rice production and ensure food security amidst changing climate. The partners are:

- Bioforsk - Norwegian Institute for Agricultural and Environmental Research (Project Co-ordinator)
- Tamil Nadu Agricultural University, Coimbatore, India
- International Pacific Research Institute, Hawaii, USA
- International Water Management Institute, Hyderabad, India

The project is funded by the Norwegian Ministry of Foreign Affairs/The Norwegian Embassy, New Delhi.

Read more: www.climarice.com