

Role of biological nitrogen fixation in rice

Yosef Tabar, s

Young Researchers and Elit Club, sari Branch, Iran Islamic Azad University, sari, Iran

Abstract: Rice (*oryza sativa L.*) is one of the most important cereal crops of the worlds. Nitrogen deficiency is one of the most important nutritional disorders in lowland rice producing. Fertilizer nitrogen has become a major input in crop production around the world. The economic and environmental costs of the heavy use of chemical N fertilizers in agriculture are a global concern, sustainability considerations mandate that alternatives to N fertilizers must be urgently sought. The biological nitrogen fixation (BNF) is a way to eliminate the usage of chemical fertilizer and also to prevent the damage to the agricultural ecosystem. Biofertilizers has already proved to be the best over the agro chemicals and have been showing the tremendous effect on the global agriculture productivity since the past two decades.

Keywords: Rice-Nitrogen fertilizer- Biological nitrogen fixation (BNF).

1. Introduction

The world rice plant is completely composed of the regularity, order and rules, through many of them are still too complicated for us to comprehend (Nachimuthu et al, 2007). Rice (*oryza sativa L.*) is one of the most important cereal crops of the worlds such as Asia, Africa, South America and Australia (Bahmanyar & Ranjbar, 2007) in terms of food, area and production (Bakhsh et al, 2011), grown in wide range of climatic zones, to nourish that mankind (Chaturvedi, 2005). Although the importance of rice declines with economic growth, demand for rice will continue to grow for many years, and this growth could occur at a pace that exceeds growth in supply. If this security of millions of poor Asians. The role of rice research is to increase supply at a rate that exceeds growth in demand through increased farm level productivity. Many factors affect growth in rice demand, but the main ones are population growth, income growth and urbanization (Dawe et al, 2000). The yield of rice is much lower than world average. It is mainly due to lack of potential varieties and management practices. Improve varieties and judicious application of fertilizer are two of the most effective means for maximizing yield of rice (Islam et al, 2006). The future need for rice (more than 30% increase by 2020 to be grown with less land in the intensive rice areas, and with new technologies in the rainfed systems, demands that science explore new frontiers (Fischer, 2000). Prices will also affect the quantity of rice demanded by consumers, but this effect tends to be small because rice is a staple food and is so important to consumers that its demand is relatively insensitive to changes in prices. Furthermore, long-term forecasts of prices are notoriously difficult to make, so these effects are not discussed further (Dawe, 2000). Rice production depends on several factors: climate, physical conditions of the soil, soil fertility, water management, sowing date, cultivar, seed rate, weed control and fertilization, nitrogen fertilizer is a major essential plant nutrient and key input for increasing crop yield (Yosef Tabar et al, 2012). With the increase in cultivation of rice, use of chemical fertilizers is also increasing simultaneously as it can rapidly give more reliable boosts to crop yield (Saikia et al, 2011). Nitrogen fertilizer is more

urgent for security rice production, many investigators studied the importance of nitrogen fertilizer rates, the highest plant height, number of panicle/m² seed weight/panicle, panicle length, grain and straw yields were obtained when the nitrogen fertilizer rates increased up to 80 kg N/ha (Sharief et al, 2006). Biological nitrogen fixation may generate benefits because of higher yields, lower use of fertilizer N, or both (Dawe, 2000).

2. The Role of Nitrogen in Rice Production

Nitrogen is a constituent of compounds such as amino acids, proteins, RNA, DNA, and several phytohormones and is thereby an essential macro element for plants (Wang and Schjoerring, 2012). It is not only the constituent of key cell molecules such as amino acids, nucleic acid, chlorophyll, ATP and several plant hormones, but also the pivotal regulator involved in many biological processes including carbon metabolism, amino acid metabolism, nucleic acid metabolism and protein synthesis (Cai et al, 2012). Nitrogen is essential for all living organisms, the synthesis of cellular proteins, amino acids, nucleic acids, purine and pyrimidine nucleotides are dependent upon N. It is the most abundant mineral element in plant tissues which is derived from the soil. However, excess N may cause significant biochemical changes in plants and may lead to nutritional imbalances (Salim, 2002). Nitrogen taken up during early growth stages accumulated in the vegetative parts of the plant and is utilized for grain formation. A large portion of the nitrogen is absorbed during differentiation. The leaves and stems contain a large portion of the nitrogen taken up by the plant (Abou-khalifa, 2012). Nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelets, reflecting on grain productivity. Excessive tillering caused by inadequate nitrogen fertilization reduced the percentage of fertile tiller, filled spikelet percentage and grain mass (Dastan et al, 2011). Rice needs 1 kg of nitrogen to produce 15-20 kg of grain. Lowland rice in the tropics can use enough naturally available N to produce 2-3 t/ha for higher yield, additional N must be applied (Ladha & Reddy, 2000).

3. Future Demand for Nitrogen Fertilizer on Rice

Among different nutrients nitrogen is one of the essential macronutrient required for proper plant growth (Gholizadeh et al, 2011). Nitrogen management is essential for rice under aerobic culture as nitrogen use efficiency is in the range of 40 to 60 percent, application of nitrogen at right time is perhaps the simplest agronomic solution for improving the use efficiency of nitrogen (Ganga Devi et al, 2012). Approximately 65% of the applied mineral N is lost from the plant-soil system through gaseous emissions, runoff, erosion and leaching. Environmental impact of this loss ranges from green house effect, diminishing stratospheric ozone and acid rain to changes in the global N cycle and nitrate pollution of surface (Saikia et al, 2012). Irrigated rice occupies 50% of total rice area and produces 75% of total rice output, further intensification of irrigated rice ecosystem is necessary to feed the growing population and maintain food security in coming years (Nachimuthu et al, 2007). Nitrogen is normally a key factor in achieving optimum lowland rice grain yields, it is however one of the most expensive inputs and in different ecosystems, many of the world's rice is grown under irrigated or rainfed lowland conditions, soil under these conditions are saturated, increasing rice yield per unit area through use of appropriate N management practices has become an essential component of modern rice production technology (Metwally et al, 2011). Moreover the production of inorganic N by the Haber-Bosch process generates huge amount of CO₂, between 0.7-1.0 tonnes per tonnes of ammonia. At the same time due to unavailability of fossil fuels, the price of chemical fertilizers is also increasing rapidly since inorganic fertilizers are derived from fossil fuels particularly natural gas. There are also problems of losses of fertilizer after application through leaching, volatilization and through denitrification overall, effects of these problems requires more concentration on greater access to expensive biofertilizer technologies, as they are ecologically sound and their application could help to minimize the global warming as well as to reduce the fertilizer input in farming practices (Saikia et al, 2012). In the past few decades, chemical fertilizers have widely spread throughout the world focusing that the soil is inert medium for plant roots, rather than as a living biosphere in which the crop is only one of hundreds or thousands of interacting species, however, it is now realized that in fields under intensive monoculture which receive heavy applications of chemical fertilizers alone, there is a slow decline in productivity, this decline occurs even in irrigated paddy fields (Siavoshi et al, 2010). Increase use of nitrogenous (N) fertilizer has greatly changed the global N-cycle and produced nitrogenous gases of environmental significance. While nitrous oxide (N₂O) emissions contribute to global greenhouse gas accumulation of ground water quality by N use in agricultural is essentially a nitrate leaching problem, despite these reasons, for the past half a century, supply of nitrogen through fertilizers has been a powerful tool for increasing the yield of cultivated plants such as cereals. Millions of tonnes of nitrogenous fertilizers are applied for crop production worldwide (Hakeem et al, 2012). Rice crop usually take half of the applied N to yield above ground biomass, the other half of the N is dissipated in the wider environmental and ecological problem. The efficient N use is critical to produce enough food for feeding the growing population and avoid large scale

degradation caused by excess N (Nachimuthu et al, 2007). Application of nitrogen fertilizers are responsible for emissions of green house gases like nitrous oxide (N₂O) and ammonia (NH₃) besides supplying nitrogen, ammonia can also increase soil acidity. Excessive nitrogen fertilizer application lead to pest problems by increasing the birth rate, longevity and overall fitness of cereal pests (Siavoshi et al, 2010). Excessive application of chemical nitrogen fertilizer can result in a high soil nitrate concentration after crop harvest, this situation can lead to increase in the level of nitrate contamination of potable water, because nitrate remaining in the soil profile may leach to ground water (Azarpour et al, 2011).

4. Potential Benefits of Biological Nitrogen Fixation

Nitrogen (N) fertilizer is a major input for rice, only 30-40% of applied N is used by the crop, however, due to losses through volatilization, denitrification, leaching and runoff (Kumar et al, 2000). Therefore, when an excess of N cannot be totally avoided, it should also be important to search for species or genotypes that are able to absorb and accumulate high concentrations of N or those which can grow and yield well under low N conditions. I.e. N-efficient genotypes to work out their physiological N uptake kinetics and finally determine the biochemical pathway of the nitrogen absorbed from the soil. This will help us in improvement of N-uptake efficiency which ultimately leads to the increase in the nitrogen use efficiency (NUE) among the crop plants as it has a practical merit because millions of tonnes of N-fertilizers are applied to the soil to increase crop productivity per unit area (Hakeem et al, 2012). Diazotrophic microorganisms are able to fix atmospheric N through biological nitrogen fixation (BNF) process. This process benefits the agriculture sector especially for reducing cost of inorganic nitrogen fertilizer. It is due to ability of the microorganisms to convert atmospheric N into ammonia (NH₃) which is useable by plants (Shaffie et al, 2012). The utilization of biological nitrogen fixation method can decrease the use of chemical nitrogen fertilizer, prevent the depletion of soil organic matter and reduce environmental pollution to a considerable extent (Azarpour et al, 2011). This situation has encouraged researchers to study the non-chemical sources of nutrients to replace them with the currently used chemical ones. Some micro organisms live in symbiosis with plants root and improve their growth, which are generally called plant growth promoting Rhizobacteria (PGPR) (Shokouri et al, 2012). Nitrogen-fixing organisms are generally active in plant root zone soil. Plants that are capable of releasing exudates exhibit higher nitrogen fixation activity in soil (Shridhar, 2012). Biological nitrogen fixation may generate benefits because of higher yields, lower use of fertilizer N, or both. Such yield increases could potentially be due to improved congruence between plant N demand and supply, resulting in an enhanced C sink and photosynthesis (Dawe, 2000). Biological nitrogen fixation is carried out only by prokaryotes, which may be symbiotic or free living in nature. It is well documented that biological nitrogen fixation mediated by nitrogenase enzymes is a process important to the biological activity of soil. Nitrogenase activity in soil depends on ecological conditions in association with the specific nitrogen fixation capabilities of certain

microorganisms and plant genotypes under various climatic conditions, however the degree of nitrogenase activity is plant specific. The nitrogen fixation activity of free-living, non-photosynthetic aerobic bacteria is strongly dependent on favorable moisture conditions, oxygen concentration and a supply of organic C substrates (Shridhar, 2012). Several bacteria that are associated with the roots of crop plants can induce beneficial effects on their hosts and often are collectively referred to as plant growth promoting rhizobacteria (Azarpour et al, 2011). Thus a significant reduction in the relative use of fertilizer N can be achieved if atmospheric N is made available to non-legumes directly through an effective associative system with some of the characteristics of legume symbiosis (Saikia et al, 2012). The biological fixation of nitrogen produced by these organisms can constitute a significant and ecologically favorable contribution to soil (Azarpour et al, 2011). Azotobacter and Azospirillum are free living (non-symbiosis), nitrogen fixing bacteria which live in Rhizosphere and improve plant growth and yield under proper condition. These bacteria generally improve plant root development, water and nutrient absorption and fix air nitrogen into soil (Shokouri et al, 2012).

5. Potential Benefits of Biological Nitrogen Fixation for Rice

The environmental benefits of BNF in rice are likely to be more substantial than the financial benefits to farmers. In many areas, the share of water pollution caused by nitrogen runoff from fertilizers is very high. Thus, a 50% reduction in the use of mineral N fertilizer would have significant health, environmental, and economic benefits such as improved quality of drinking water and restoration of habitats for aquatic life (Dawe, 2000). Diazotrophs can be found in many rice growing areas, either free-living or associated with the legume *Sesbania* or the aquatic water fern *Azolla*, in another naturally occurring situation, nitrogen-fixing bacteria of genus *Rhizobium* (known as rhizobia) are known to endophytically associate with rice plants, colonizing their root tissues without the formation of true root nodules (Britto & Kronzucker, 2004). Nitrogen feeding due to considerable effect on the growing parameters and physiological properties of rice is very important as by selecting nitrogen biologic and chemical fertilizer rate suitably could reach to balanced composition of growing index and supplied yield improvement (Azarpour et al, 2011). The nitrogen fixed by these bacteria is directly or indirectly available to the crop, with free-living bacteria annually, under greenhouse conditions, the amount of biologically fixed nitrogen taken up by rice can be as much 80% of its nitrogen uptake, and is strongly cultivar-dependent (Britto & Kronzucker, 2004). BNF may give rise to a yield penalty because the energy requirement of nitrogen fixation may necessitate translocation of some carbon away from the grain, this concern may be mitigated to some extent because rice is low in protein, this implied that much lower rates of nitrogen fixation will be required (relative to legumes), with correspondingly less drain on the plants photosynthates (Dawe, 2000). Large amounts of nitrogen derived from biological fixation have been shown to be present in rice plant (Muralib et al, 2012). Acetylene reduction assay, N studies and N balance studies showed that the contribution of N₂ fixation associated with root is about 20% of the N of rice. Identification of rice genotypes capable of stimulating

associative N₂ fixation is an important goal for rice agriculture. Heterotrophic bacterial BNF is 7 kg N ha⁻¹, ranging from 11-16 kg N ha⁻¹ which contributes 16-21% of total rice N requirement (Shrestha & Maskey, 2005). The inescapable conclusion from the above is that rice productivity is severely limited by available N, the highest sustainable yields with available BNF could reach 3-4 T/ha in the rainfed lowlands and 4-5 T/ha in irrigated rice, yield beyond those levels will not be attainable without chemical N fertilizer or innovative forms BNF (Kush & Bennetty, 1992). Effect of biofertilizer on rice growth and development and concluded that inoculating rice transplants with *Azospirillum* increases leaf area, plant height, panicle length and the number of grains/panicle (Shokouri et al, 2012). The biological nitrogen fixation (BNF) associated with rice roots under SRI practices and have identified the role of *Azospirillum* as a source for meeting plant nitrogen needs (Randriambarisoa, 2002). *Azotobacter* act as one of the important biofertilizer for rice and other cereals, it can apply by seed dipping and seedling root dipping methods, *Rhizobium* is able to induce the shoot and root growth in rice plant, *Azospirillum* population enhances the utilization of P and NH₄ compounds in rice plants, *Azolla* is able to reclaim soils reducing the weed infestations in rice crops and it was also used in waste water treatment and heavy metal degradation process (Kumar & Rao, 2012).

References

1. A.A.B. Abou-khalifa, "Evaluation of some rice varieties under different nitrogen levels," *Advances in Applied Science Research*, 3 (2), pp.1144-1149, 2012.
2. A.A. Muralib, O. Radzia, Y. Shukor, U.A. Nahe, "Effect of nitrogen fertilizer on hydrolytic enzyme production, root colonisation, N metabolism, leaf physiology and growth of rice inoculated with *Bacillus* sp. (Sb42)" *Australian journal of crop sciences*. *AJCS* 6(9), PP:1383-1389, 2012.
3. A.E. Sharief, S.E. El-Kalla, A.T. El-Kassaby, M.H. Ghonema, G.M.Q. Abdo, "Effect of bio-chemical fertilization and times of nutrient foliar application on growth, yield and yield component of rice" *Journal of Agronomy*, 5(2), PP:212-219, 2006.
4. A. Gholizadeh, M.S.M. Amin, A.R. Anuar, W. Aimrun, M.M. Saberioon, "Temporal variability of SPAD chlorophyll meter readings and its relationship to total nitrogen in leaves within a Malaysian paddy field" *Australian Journal of Basic and Applied Sciences*, 5(5), PP:236-245, 2011.
5. B.S. Shridhar, "Review: Nitrogen Fixing Microorganisms" *International Journal of Microbiological Research*, 3 (1) PP: 46-52, 2012.
6. D. Dawe, "The potential role of biological nitrogen fixation in meeting future demand for rice and fertilizer" *International rice research institute*, 2000.
7. D.T. Britto, H.J. Kronzucker, "Bioengineering nitrogen acquisition in rice: can novel initiatives in rice genomics and physiology contribute to global food security?" *BioEssays*, 26, PP:683-692, 2004.
8. E. Azarpour, F. Tarighi, M. Moradi, H.R. Bozorgi, "Evaluation effect of different nitrogen fertilizer rates under irrigation management in rice farming" *World Applied Sciences Journal*, 13(5), PP.1248-1252, 2011.

9. G.Nchimuthu, V.Velu, P.Malarvizhi, S.Ramasamy, L.Gurusamy, "Standardisation of leaf colour chart based nitrogen management in direct wet seeded rice (oryza sativa L.)" *Journal of Agronomy*, 6(2),PP:338-343,2007.
10. G.S.Kush, J. Bennetty, "Nodulation and nitrogen fixation in rice,potential and prospects" *International rice research institue*, PP:1-11 ,1992.
11. H.Cai, Y.Lu, W.Xia,T.Zhu,X. Lian, "Trans criptome response to nitrogen starvation in rice" *Indian academy of sciences, J.Bio.Sci*, 37(4),PP:731-747, 2012.
12. I.Bakhsh, H.Ayatullah, K.Usman, I.Ayatullah , M.Qasm, S.Anwar, S.Javaria, "Effect of plant growth regulator application at different growth stageson the yield potential of coarse rice" *Sarhad.J.Agric*, 27(4), PP:513-518, 2011.
13. I.Chaturvedi , "Effect of nitrogen fertilizers on growth,yield and quality of hybrid rice(oryza sativa L.)" *journal of central european agricultural*, 6(4) PP:611-618, 2005.
14. J.K. Ladha, P.M.Reddy, "Steps toard nitrogen fixation in rice. The Quest for nitrogen fixation in rice" *International rice research institue*, PP:33:46, 2000.
15. K.R. Hakeem, R.Chandna, P.Ahmad, A.Ahmad, M.Iqbal, "Physiological and molecular analysis of applied nitrogen in rice genotypes" *Rice ScienceDirect*,19(1),2012.
16. K.S.Fischer, "Forntier project on nitrogen fixation in rice:looking ahead.The Quest for nitrogen fixation in rice" *International rice research institue*,PP:25-32, 2000.
17. L.Wang, K.J.Schjoerring, "Seasonal variation in nitrogen pools and 15N/13C natural abundances in different tissues of grassland plant's" *Biogeoscicnes*. 9,PP:1583-1595,2012.
18. M.A.Bahmanyar,G.A. Ranjbar, "Response of rice cultivar to rates of nitrogen and potassium application in field and pot conditions." *Pakistan journal of biological sceinces*, 10(9),PP.1430-1437,2007.
19. M.D. Islam, M.Hasanuzzaman, M.Rokonuzzman, " Effect of split application of nitrogen fertilizer on morphophysiological parameters of rice genotypes" *International journal of plant production*, 3(1),PP:1735-6814, january2009.
20. M.Ganga Devi,M, S.Tirumala Reddy, V.Sumati, T.Pratima, K.John , "Nitrogen Management to improve the nutriet uptake, yield and quality parameters of scented rice under aerobic cultur" 3(1),PP: 340-344, 2012.
21. M.J.Shakouri, A.V.Varasteh Vajargah, M.Ghasemi Gavabar, S.Mafakheri, M.Zargar, "Rice Vegetative Response to Different Biological and Chemical Fertilizers" *Advances in Environmental Biology*, 6(2), PP: 859-862, 2012.
22. M.Salim, "Nitrogen induced changes in rice plants:effects on host-insect interoductions" *pakistan J. Agric. Res*. 17(3),PP:210-218, 2002.
23. M.Siavoshi, A.Nasiri, S.L.Laware, "Effect of Organic Fertilizer on Growth and Yield Components in Rice (Oryza sativa L.)" *Journal of Agricultural Science* , 3(3),PP: 217-224, 2011.
24. R.K.Shrestha, S.L. Maskey, "Associative Nitrogen Fixation in Lowland Rice" *Nepal Agric. Res. J*, 6,PP:112-121, 2005.
25. R.M.Kumar, K.Padmja, S.V.Subbaiah, "Varietal response to different nitrogen management methods in an irrigated transplanted rice ecosystem in a vertisol andhra pradesh india" *International Rice Research Note(IRRN)*, PP:32-34, 2000.
26. R.P.Randriamibarisoa, "Research Results on Biological Nitrogen Fixation with the System of Rice Intensification" *Cornell International Institute for Food, Agriculture and Development, Research Report: Madagasca*. PP:148-157, 2002.
27. S.Dastan, M.Siavoshi, D.Zakavi, A.Ghanbari-malidarreh, R.Yadi, E.GhorbanniaDelavar, A.R.Nasiri, "Application of nitrogen and silicon rates on morphological and chemical lodging related characteristics in rice (oryza sativa L.) north of iran" *Journal of agricultural science*, 4(6),PP:1-5.2012.
28. S.P.Saikia, D.Bora, A.Goswami, K.D.Mudoi, A.Gogoi, "A review on the role of Azospirillum in the yield improvement of non leguminous crops" *African Journal of Microbiology Research*, 6(6), PP:1085-1102, 2012.
29. S.R.S.Kumar, K.V.B.Rao, "Biological nitrogen fixation:A Review" *International journal of advanced life sciences*, (1),PP:1-6, 2012.
30. S.Shaffie, A.M.Ghazali, N.Najimudin, "Estimation of Nitrogenase Enzyme Activities and Plant Growth of Legume and Non-legume Inoculated with Diazotrophic Bacteria" *Malaysian Journal of Microbiology*, 8(2), pp:123-126, 2012.
31. S.Yoseftabar, A.Fallah, J.Daneshiyan, "Comparing of yield and yield components of hybrid rice(GRH1) in different application of nitrogen fertilizer" *International journal of biology*, 4(3),PP:60-65,2012.
32. T.F.Metwally, E.E.Gewail, S.S.Naeem, "Nitrogen respose curve and nitrogen use efficiency of egyptian hybrid rice" *J,Agric,Res,Kafer El-Sheikh Univ*, 37(1),PP:73-84, 2011.