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Review on the Role of Biological Nitrogen Fixation in the Environmental Terms

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ABSTRACT

Biologically active product more appropriately called as "microbial inoculants" contains active strength of selective microorganisms like bacteria, algae, fungi; alone or in combination helps in increasing crop productivity by biological nitrogen fixation. Biological nitrogen fixation , the second most important biological process on earth after photosynthesis involves conversion of atmospheric nitrogen (N2) to ammonium, a form of nitrogen that can be utilized by plants The rhizobia are a group of Gram-negative bacteria that form species-specific symbioses with legume plant. The Rhizobium-legume symbiosis is superior to other nitrogen fixing systems as symbiotic nitrogen fixation is an important source of nitrogen, and the various legume crops and pasture species often fix as much as 200 to 300 kg nitrogen per hectare. Thus emphasis should be given for establishment of efficient symbiotic N2-fixing systems in legumes. The work pertaining to different aspects on legume - Rhizobium symbiosis have been covered in the review. Biological nitrogen fixation is estimated to be approximately 150 to 200 million tonnes annually on the earth's surface. Biological nitrogen fixation contributes about 100 million tons of nitrogen for terrestrial ecosystems, 30 to 300 million tons for marine ecosystems and 20 million tons from chemical fixation due to atmospheric phenomena. Besides the unique nature of association, the importance of the association from the point of view of nitrogen economy and soil fertility also seems to have generated so much interest on the subject within the scientific community. Most researches' results indicate that Rhizobium inoculation is promising biofertilizer because it is cheap, easy to handle and improves plant growth. Therefore, legume-rhizobia symbiosis can provide easy and inexpensive way to enhance soil fertility and improve crop production.

Introduction

The association of rhizobia with leguminous plants is one of the most thoroughly studied subjects in the biological sciences. N_2- fixing ability of rhizobia has resulted in their use as biofertilizers and hence they have received more attention now a days. Besides the unique nature of association, the importance of the association from the point of view of nitrogen economy and soil fertility also seems to have generated so much interest on the subject within the scientific community. The work pertaining to above different aspects on legume - *Rhizobium* symbiosis have been covered in the review.

Importance of BNF in legumes

An exponential rise in world population indicates the need for increased crop production. Chemical nitrogen fertilizers will continue to serve for increasing grain production until a predictable future, but efforts should also be oriented towards augmenting biological nitrogen fixation. Biologically active product more appropriately called as "microbial inoculants" contains active strength of selective microorganisms like bacteria, algae, fungi; alone or in combination helps in increasing crop productivity by biological nitrogen fixation. Legumes have long been recognized and valued as "soil building" crops. Most legumes can obtain between 50 and 80% of their total nitrogen requirements through biological fixation. By contrast, the legume has been characterized as being less responsive to the application of fertilizer N; the fertilizer efficiency for legumes generally ranges from 20 to 50%. (Mengel *et al.,* 1987). It is in this context, the use of the nitrogen fixing bacteria in agricultural practices is gaining importance (Baker, 1992). Hardarson *et al.,* (1993) reported that the root nodule rhizobia approximately reduce 20 million tons of atmospheric nitrogen to ammonia which is 50% - 70% of the world biological nitrogen fixation.

The rhizobia are a group of Gram-negative bacteria that form species-specific symbioses with legume plant, Nitrogen fixation, the reduction of atmospheric dinitrogen (N2) to ammonia (NH3), by rhizobia only occurs during symbiosis and provides a significant proportion of available nitrogen in the biosphere. The reduction of atmospheric nitrogen into ammonia is the second most important biological process on earth after photosynthesis (Sylvia, 2005). The *Rhizobium*-legume symbiosis is superior to other nitrogen fixing systems due to its high potential. Thus emphasis should be given for establishment of efficient symbiotic N_2-fixing systems in legumes. Symbiotic nitrogen fixation is therefore of great ecological and socio-economic importance (Sanaa and Fawziah, 2005).

Peoples *et al.,* (1995) reported that the symbiotic nitrogen fixation is an important source of nitrogen, and the various legume crops and pasture species often fix as much as 200 to 300 kg nitrogen per hectare. Globally, symbiotic nitrogen fixation has been estimated to amount to at least 70 million metric tons of nitrogen per year (Brockwell *et al.,* 1995). He reported that the rhizobia in root nodules are estimated to carry out between 50-70% of the world'sbiological nitrogen fixation and the estimated annual biologicalfixation of atmospheric nitrogen varies between $100x10^6$ and $180x10^6$ Mt per year.

Peoples *et al.,* (1995) described that the rhizobia are of great importance for nitrogen acquisition through symbiotic nitrogen fixation in a wide variety of leguminous plants. Plants benefit from nitrogen-fixing bacteria when the bacteria die and release nitrogen to the environment or when the bacteria live in close association with the plant. In legumes, the bacteria live in small growth on the root called nodule. Within these nodules, nitrogen fixation is done by the bacteria and the NH_3 produced is being absorbed by the plant.

Biological nitrogen fixation is estimated to be approximately 150 to 200 million tonnes annually on the earth's surface. The symbiotic relationships between specific soil micro-organisms and plants are the most significant contributor of BNF in most terrestrial ecosystems. Biological nitrogen fixation involves conversion of atmospheric nitrogen (N_2) to ammonium, a form of nitrogen that can be utilized by plants (Vessey *et al.,* 2003). Rakash and Rana (2013) reported that the biological nitrogen fixation contributes about 100 million tons of nitrogen for terrestrial ecosystems, 30 to 300 million tons for marine ecosystems and 20 million tons from chemical fixation due to atmospheric phenomena.

Roychowdhury *et al.,* (2013) reported that the legume-rhizobial symbiosis has a large impact on success of legumes hence the atmospheric nitrogen the organisms fix can be more than the fertilizer nitrogen an average farmer can afford to buy and apply. Therefore, legume-rhizobia symbiosis can provide easy and inexpensive way to enhance soil fertility and improve crop production.

Effect of biological N_2 fixation on soil N balance

In addition to the utilization of fixed N_2, the uptake of soil nitrogen was also reported to be more in nodulated and N_2-fixing soybean plants than in case of non-nodulated control plants (Jensen and Sorensen, 1988). Similar observations were reported in case of groundnut (*Voandzeia subterranea*) where plants inoculated with rhizobia accumulated significantly more N than that in case of mineral nitrogen supplied control plants (Brooks *et al.,* 1988).

Similarly, for soybean grown with different starter N levels after rice which received different fertilization levels, the N balances with seed and stover removed ranged from -12 to -35 kg ha^{-1} in northern Thailand (Jefing *et al.,* 1992).But positive N balances of upto 136 kg ha^{-1} for several legume crops following seed harvest had been shown by Peoples and Crasswell (1992). However, with crop residues removed from the field the net N balances for groundnut were -27 to -95, for soybean -28 to -104, common bean -28, green gram -24 to -65 and cowpea -25 to -69 kg ha^{-1} (Wani *et al.,* 1995). Net nitrogen balances calculated for different cultivars of pigeonpea and chickpea grown at Patancheru and Gwalior respectively indicated that all studied varieties depleted soil nitrogen (Wani *et al.,* 1995).

Sharma and Upadhyay (2001) observed that seed inoculation influenced the plant height and dry matter accumulation at all stages of crop growth. Being an important kharif legume, urdbean, *Vigna mungo* (L.) fixes atmospheric nitrogen and improves the soil fertility. Black gram can obtain nitrogen by atmospheric fixation in their root nodules in symbiosis with soil rhizobia and thus has a potential to yield well in nitrogen deficit soils. A legume plant having effective root nodules not only can meet its own nitrogen requirement but also enrich the soil nitrogen content, thereby improving soil fertility and sustainability (Kannaiyan2002). BNF offers an economically attractive and ecologically sound means of reducing external N input. It contributes to the replenishment of soil N, and reduces the need for industrial N fertilizers (Larnier *et al.,* 2005).

It is widely believed that legumes improve soil fertility because of their N_2-fixing ability. However, in order to assess the role of biological nitrogen fixation in the sustainability of different cropping systems, in addition to the amount of N_2 fixed by the component legume crop the overall nitrogen balance of the system needs to be considered. Biological nitrogen fixation contributes to the replenishment of soil N, and reduces the need for industrial N fertilizers (Larnier *et al.,* 2005). It offers an economically attractive and ecologically sound means of reducing external N input. Inoculated treatments showed significant increase in the total N content of soil over control. The highest increase in soil N 22.91 per cent over control was recorded in case of SB-16. (Patra *et al.,* 2008).

Most researches results indicate that *Rhizobium* inoculation is promising biofertilizer because it is cheap, easy to handle and improves plant growth. Akhtar *et al.,* (2012) reported that *Rhizobium* and *Azotobacter* significantly increased the lentil plant biomass (27.67g/pot), number of nodules (68.6/plant), nodular mass (1.95 g/plant), root length (39 cm), shoot length (26.3cm), root weight (7.2 g/pot) and shoot weight (6.8g/pot) at full dose of fertilizer. Biomass yield with *Rhizobium* (27.13 g/pot) Chemical analysis of plant matter showed significantly high value of nitrogen (4.4%) due to co-inoculation followed by *Rhizobium* alone (4.21%) at full dose of fertilizer. The use of legume species is of great importance because they may provide nitrogen to the system through N2 fixation and supply nitrogen without the application of mineral fertilizers (Berger *et al.,* 2013).

Saleh *et al.,* (2013) studied the effect of three *Rhizobium* strains isolated from different species of legumes (RLc107 from lentil, RCa 220 from chick pea and RVm 307 from black gram) on nodulation of two black gram varieties. *Rhizobium* inoculation improved nodulation in both the varieties than that of uninoculated control. The highest value for nodule number (58.45) per plant, nodule fresh weight (46.11mg) per plant and nodule dry weight (12.07 mg) per plant were observed in BINA MASH-1 when inoculated with *Rhizobium* strain RVm 307. Therefore, legume-rhizobia symbiosis can provide easy and inexpensive way to enhance soil fertility and improve crop production (Roychowdhury *et al.,* 2013). As per Lalitha and Sam Immanuel, 2013 Microbial inoculation induced significant changes in soil characteristics. Inoculation in black gram and green gram significantly enhanced the N (180, 170 mg/Kg soil), P (6, 8.2 mg/Kg soil) content of the soil and K (171, 188 mg/Kg soil).

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