PRODUCTION AND UTILIZATION OF LEGUME INOCULANTS (RHIZOBIUM) IN INDIA

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The deterioration of soil quality due to imbalance and abysmal use of agrochemicals, has been a major problem faced by the Indian agriculture in the recent decades. Besides these, recent climatic changes further exacerbated the gravity of problem. Soil microorganism is the key biological agent for boosting the availability of plant nutrients thus facilitating better plant growth and development. Biofertilizers are usually the carrier based microbial preparations that may enhance the plant growth through nutrient uptake and/or growth hormone production (Brahmapraakash and Sahu, 2012). These are cheap and renewable sources of plant nutrients to supplement the chemical fertilizers.

Biofertilizers includes, nitrogen fixers e.g *Rhizobium sp., Azotobacter sp., Azospirillumsp., Azolla sp.,* Blue Green Algae (*Nostoc sp., Anabena sp.*), *Gluconoacetobacter sp.,* phosphate solubilizers (*Bacillus subtilis, B. circulans, B. megaterium var. phosphaticum*), phospahte mobilizers (Arbuscular mycorrhizal fungi i.e. *Glomus, Gigaspora, Scutellospora, Acaulosporaand Paraglomus*), potash mobilizers (*Frateuria aurantia and Bacillus sp.*), Zinc solubilizers (*Bacillus sp.*) and Plant Growth Promoting Rhizobacteria (*Pseudomonas putida* and *P. fluorescens*) etc.

RHIZOBIUM BIOFERTILIZERS

Rhizobium

Rhizobium belongs to bacterial family Rhizobiaceae. It includes the following genera: *Rhizobium, Bradyrhizobim, Sinorhizobium, Azorhizobium, Mesorhizobium and Allorhizobium* (Graham and Vance, 2000). The taxonomy of *Rhizobium* tends to change frequently. *Rhizobium* was initially classified into cross inoculation groups based on its ability to nodulate different legumes (Fred *et al*., 1932). For example, the species of *Rhizobium* which form association with different legume roots, such as *R. leguminosarum* (pea, lentil), *R. lupine* (lupinus), *R. trifolii* (clover), *R. meliloti* (alfalfa, fenugreek), *R. phaseoli* (beans) etc. Based on growth rate they are classified into fast growing (*Sinorhizobium*) and slow growing rhizobia (*Bradyrhizobium* sp.) (Quispel, 1974). Further, based on 16s rRNA sequencing rhizhobia were classified into ten genera, some are phylogentically outside traditional rhizobia but do carry nod genes encoding for Nod factors (Raychaudhuri *et al*., 2007). *Rhizobium* sp. infects the root of legume plants and form root nodules (Figure1 and 2). Within the nodules, nitrogen (N_2) is reduced to ammonia which is incorporated to the plant as various products like proteins, other nitrogeneous compounds and vitamins. The quantity of N_2 fixed by *Rhizobium* varies with the species of legumes and the prevailing environmental conditions. *Rhizobium* fixesa approximately 50-100 kg N/hectare thus can reduce the use of chemical fertilizers. *Rhizobium* biofertilizers have been found to increase the yield of leguminous crops by 10-35%.

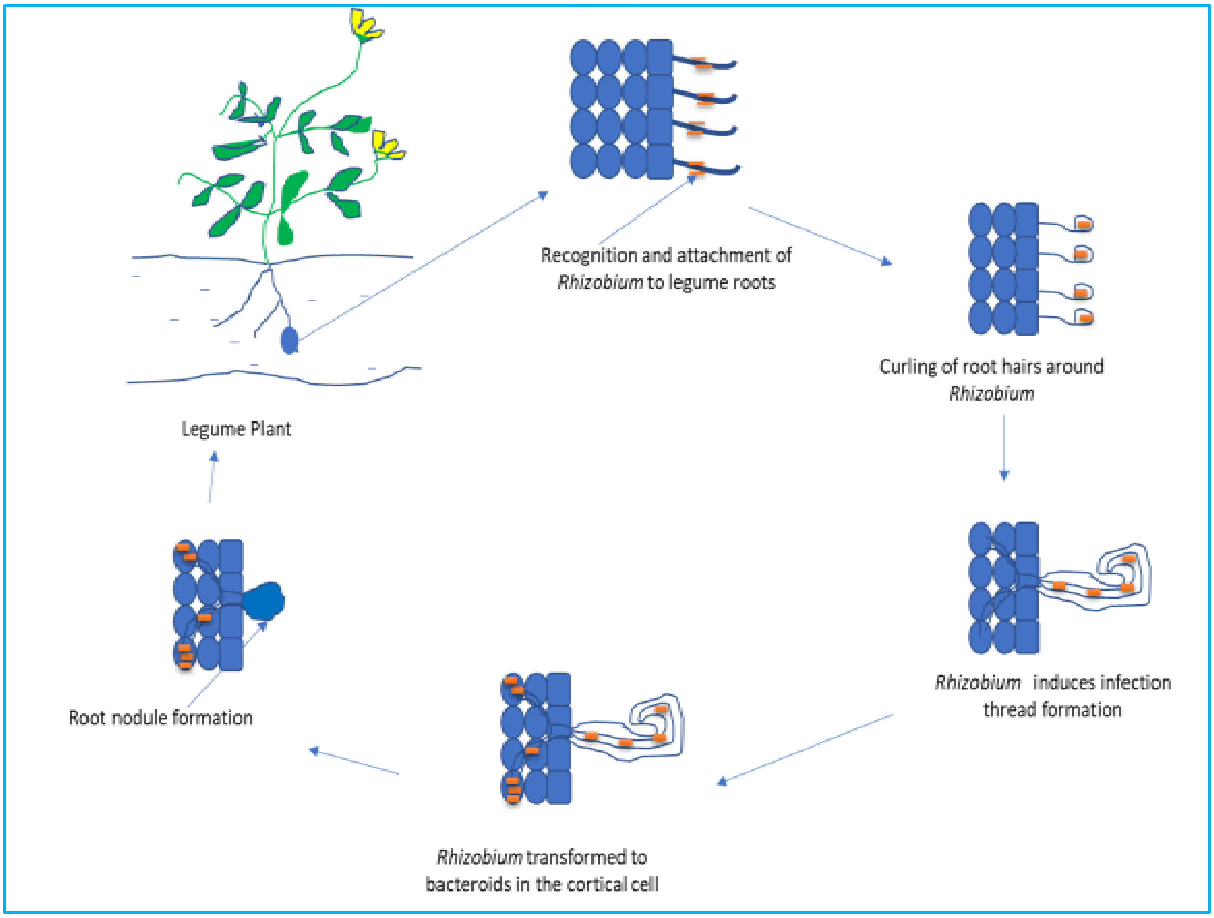

Figure.1 Mechanism of nodule formation by *Rhizobium* sp. in legumes (Adapted from Singh *et al*., 2019)

Figure. 2 Root nodulation in chickpea after *Rhizobium* inoculation

RHIZOBIUM BIOFERTILIZER FORMULATIONS

Rhizobium biofertilizers are available in the form of carrier based and liquid formulations. For the preparation of carrier based biofertilizers, different solid carriers i.e. peat, lignite, charcoal are used. Similarly for liquid based formulation, polyvinyl pyrrolidone (PVP, 0.5%), polyvinyl alcohol, methyl cellulose, polyethylene glycol (PEG, 0.5%) and gum Arabic (GA, 0.5%) are used (Tittabutr *et al*., 2007). The liquid formulation contains a high microbial load of 10^{10} - 10^{12} cells/ml and has shelf life of more than two year. These biofertilizers are manufactured by government and private agencies and are sold at a reasonable price. Rhizobium biofertilizers are recommended for pulses, leguminous oilseeds (soybean, groundnut) and leguminous fodder crops.

STATUS OF RHIZOBIUM BIOFERTILIZERS PRODUCTION IN INDIA

About 10726 Metric Tonnes (MT) of carrier based and 786 Kilolitre (KL) of liquid based Rhizobium biofertilizers were produced in India during 2017-18 (NCOF, 2018). Both the carrier based Rhizobium biofertilizer and the liquid formulation constitute about 9% of total biofertilizer production. The highest carrier based Rhizobium biofertilizers was produced in Karnataka (2784 MT) where as in case of liquid base, highest production was observed in Gujarat (290 KL).

POTENTIAL FOR PRODUCTION AND UTILIZATION OF RHIZOBIUM BIOFERTILIZERS

In India, about 25.3 million hectares of land is under pulses cultivation with a production of 18.8 million tonnes (GoI, 2018). Apart from pulses other crops for which Rhizobium inoculation is practiced are mainly oilseed crops like groundnut and soybean. These crops are grown in 4.91and 10.47 million ha respectively (GoI, 2018).The highest requirements of Rhizobium biofertilizers can be quantified through an over-simplified approach multiplying the total legume area by dosage per hectare (Barman *et al*., 2017). Hence, considering the area under cultivation during the year 2017-18 a total of 20, 330 tonnes of carrier based Rhizobium biofertilizer or 8132 Kilolitre liquid based Rhizobium biofertilizer is required for pulse and oilseeds crop. However, production is less than the demand. Also, in several states of India there is less or even no production of Rhizobium biofertilizers (NCOF, 2018), hence there is a huge potential for its production and utilization.

REASONS FOR GAP IN THE PRODUCTION AND UTILIZATION OF RHIZOBIUM BIOFERTILIZERS

The gap in Rhizobium biofertilizers utilization is due to non-adoption by farmers because of several reasons (Figure 3) such as biofertilizers have limited nutrient mobilization in comparison to chemical fertilizers and slow impacts on crop growth, inconsistent responses in the field under varied agro-ecological niches and cropping systems and lack of quality assurance. Also some times, despite inoculating with good quality of efficient rhizobial strain, the effect in field is masked due to adverse soil biotic (competition with native flora) and abiotic factors (extreme soil pH, moisture fluctuation, presence of toxic elements and chemicals etc). The reason for the gap exists between demand and supply of biofertilizers is because of dwindling number of culture collection banks which has lead to loss of hundreds of strains in the last15 years. The constraints related to production technology are, lack of carrier suitable carrier materials, biofertilizer formulations and storage facilities. Also because of improper transportation facilities lack of trained personnel, awareness among the famers and inefficient delivery systems of biofertilizers to the beneficiaries have led to lesser adoption by the farmers .

STRATEGIES TO IMPROVE THE PRODUCTION AND UTILIZATION RHIZOBIUM BIOFERTIIZERS

Selection of Rhizobium strain with higher nitrogen fixing efficiency coupled with tolerance to adverse climatic conditions, suitable carrier material which can sustain the survival for long time, improvement in formulation technology, introduction of automation facilities for handling and packaging of products are required for timely supply quality biofertilizers in required quantity. Similarly, creating awareness among end users using latest technologies like mobile apps regarding the availability and the benefits of Rhizobium biofertilizers are the need of the hour.

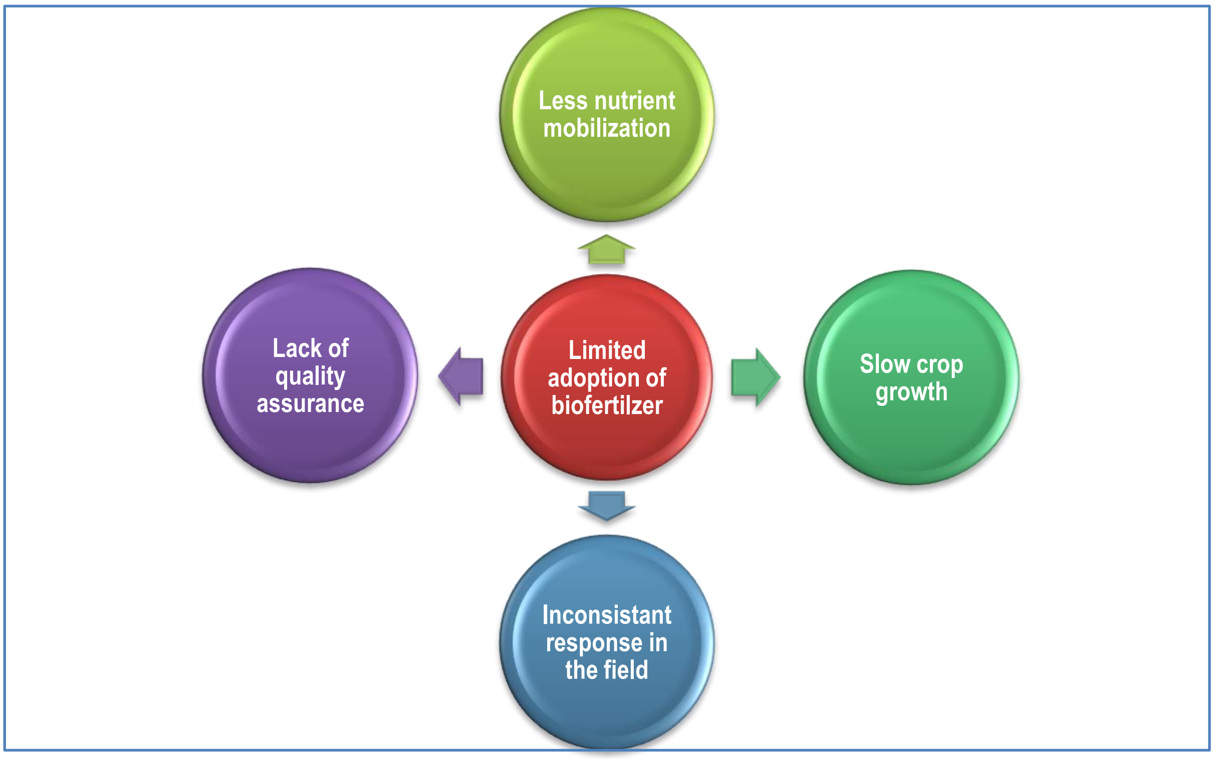

Figure 3. Possible reasons for limited adoption of biofertilizer by farmers

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