

Technology 9: Bio-inoculants

Mixed Consortium Biofertilization

Use of mixed biofertilizers (BIOMIX) containing a consortium of N fixers, P solubilisers and PGPR (plant growth promoting rhizobacteria) has been found to promote the growth of cereals, legumes and oilseeds better than their individual application. For example, in Tamilnadu inoculation of consortia of *Azospirillum*, PSB and PGPR on rice variety 'whiteponni' in the presence of 75% N and P, recorded 13% higher grain yield than with 100% NP, besides saving 25% NP. *Rhizobium*, RBG 314 and P solubilizer, AMT 1001, the promising and compatible combination developed in Andhra Pradesh gave 15% increase in yield of blackgram variety LBG 20. Chilli is an important crop in Andhra Pradesh of great commercial value. *Azospirillum* strains were developed and inoculated on chillis which yielded 25% yield increase over 100% RDF (recommended dose of fertilizers) and 30% over 75% RDF. In vertisols of Maharashtra, inoculation of *Azotobacter* and PSB on blackgram, soybean and pigeonpea increased the seed yields significantly by 150-250 kg/ha over control even at 100% RDF.

Integrated application of Biofertilizers with FYM

Organics have been found to boost the proliferation of *Rhizobium* and enhance nodulation, nitrogen fixation, N and P uptake in legumes and oilseeds. In vertisols of Maharashtra, *Rhizobium* inoculation of groundnut increased the pod yield by 3.9 q/ha while FYM alone @ 5t/ha increased it by 1.5 q/ha, combined application of FYM and *Rhizobium* increased it by 7.3 q/ha. Similarly in greengram use of *Rhizobium* along with FYM gave 2.8 q/ha additional grain yield respectively over unmanured, uninoculated control. These and similar results in pigeonpea led to the recommendation released by from AICRP on BNF at Parbhani 'Apply *Rhizobium* inoculants along with FYM @ 5 t/ha'.

N savings due to microbial inoculation in oilseed-cereal rotation

In soybean-wheat rotation in vertisols wheat yields at Jabalpur following soybean are higher (+11%) than those following sorghum. Wheat yield at 90 kg with biofertilizers (*Rhizobium* in soybean and *Azotobacter* in wheat) were comparable to 120 kg N, thus saving 30 kg N/ha.

Inoculation alongwith micronutrients application in acid soils

In acid soils (of Orissa), application of micronutrients (molybdenum and cobalt) boosts nodulation, BNF and yield of legumes. In green gram *Rhizobium* inoculation increased the grain yield (26 %). Application of micronutrients alongwith inoculation further enhanced the grain yield dramatically (+78 %) over uninoculated control resulting in additional BNF of 24 kg ha⁻¹.

Biofertilizers Improve Fertilizer Use Efficiency

Research leads by the AINP on Biofertilizers-Bhubaneswar center on improving Fertilizer Use Efficiency (FUE), were tested in three farmers fields in Dhenkanal district of Orissa in acidic sandy loams (pH 5.2-5.6). Bioinoculants (*Azotobacter* + *Azospirillum*) improved the yield of Okra, tomato and brinjal by 13.5-20.0 % over farmers practice and 8.5-14.3% over recommended dose of fertilizers (RDF). Most significantly the apparent FUE increased in the case of nitrogen by 6-15% for nitrogen, 10-22 % for phosphorus, 13-28% for potassium and 2.7-5.0 % for sulphur.

Averaged together they represent an increase in the yield of 16.6 % over farmers practices and 11.3% over RDF due to the use of bioinoculants. Average increase in FUE due to inoculants was 11.3% in the case of N, 14.2 % in the case of P, 20 % in the case of K and 3.6% in the case of S.

Biofertilization in Drylands

Crops in dryland areas suffer due to moisture stress and low native soil organic matter and nutrient status. Use of integrated nutrient management practices in loamy sand soils in Haryana showed that inoculation of bacterial biofertilizers like *Azospirillum* and *Pseudomonas* on pearl millet, wheat and mustard gave 10-22% increase in yield in grain yield when applied alongwith 75% recommended doses of nitrogen. Fifty two demonstration trials on mixed biofertilizer inoculation in pearl millet in farmers fields (District of Hisar, Bhiwani, Jajjhar, Mahendergarh and Rewari) resulted in an average increase of 5% increase in grain yield and 6% increase in fodder yield at 75% RDN, giving an additional monetary return to the farmers of Rs. 780/ha (net return)

Biofertilizer Technology

In efforts at improving the shelf life of inoculants, survival of *Azotobacter*, *Azospirillum* and PSB was found to be better (~10 fold) in charcoal based inoculants than lignite based ones at the end of 90 days at HAU, Hisar. For improving the shelf life of *Rhizobium*, *Bradyrhizobium* and phosphate solubilizing bacteria-*Bacillus* sp. addition of 2% humic acid to lignite and vermiculite carrier based cultures enhanced the survival of all the bacteria upto 150 days of storage. A new medium for co-culturing *Azospirillum lipoferum*, *Bacillus* and *Pseudomonas fluorescens* was formulated at TNAU, Coimbatore and staggered inoculation was used to get high titre. In lignite carrier this co-culture had a population of 10^7 - 10^8 cells /g at 6 months in contrast to individual inoculant count of 10^8 - 10^9 /g. Liquid inculant of co-culture prepared by addition of 2% PVP supported titre of 10^9 cfu/ml upto six months. Similarly at ANGRAU, Amaravathi, liquid formulations LM2 and LM4 retained maximum population of *Azospirillum* i.e., 10.7 and 10.64 log CFU/ml after one year..

Demonstration of Bacterial Inoculants

Seed inoculation of leguminous oilseeds-groundnut and soybean with *Rhizobium* were successfully demonstrated in farmers fields in 'Front Line Demonstrations' in the states of Tamilnadu, Maharashtra and Madhya Pradesh. Inoculation of vegetable crops in Orissa in acid soils in farmers fields led to significant benefits. All these led to :

- Better adoption of technology
- Better seed yields
 - (i) Additional groundnut pod yields 14-23% in Tamilnadu and 23-28% in Maharashtra
 - (ii) Additional soybean seed yields of 9-16% in Madhya Pradesh
 - Reducing the dependence on costly chemical fertilizers
 - (iii) Saving of 20-30 kg fertilizer- N per hectare, as starter dose, was achieved.
- Better vegetable yields: 9-14% increase in yield of tomato, brinjal, okra upon bioinoculation (BI) of *Azotobacter*, *Azospirillum* and PSB over and above the recommended nutrient management practices.

These efforts have contributed to other on-going efforts in increasing the production of microbial inoculants by the states and diffusion of BNF technology among the farmers.

Economic Benefits

From the average values of BNF in legumes, cereals, oilseed, fibre, horticultural and fodder crops in India cultivated over 190 million ha; A conservative estimate for BNF inputs in India amount to 4.20 million tonnes of nitrogen per year which at the current prices of urea works out to Rs. 4410 crores every year. Considering that BNF efficiencies are at least twice that of fertiliser urea nitrogen, the corresponding monetary benefits would also be twice as much. Extrapolation of the benefits of biofertilizer consumption of 13,000 t/yr (taking into consideration the average yield, N and P saving benefits observed in AICRP-BNF centres all over India in last 20 years) show that inoculation benefits amount to about N and P inputs of 0.32 and 0.13 million tonnes respectively equivalent to a monetary equivalent of Rs. 600.2 crores per annum.