The soil microorganisms be[illegible] production and protection and [illegible]intenance of soil health and fertility are known for centuries. However, in the present day intensive agricultural practices the contributions of these microorganisms have been overlooked, since their effects are more pronounced under sustainable conditions as compared to nutrient sufficient soil environment. Use of excessive inorganic fertilizers and chemical pesticides in intensive cropping has destroyed the microbial equilibrium in soil where microorganisms harmful to plant growth have predominated over the beneficial ones. However the Soil Biologists continued their efforts to highlight the role of the beneficial forms and have understood the phisiology, biochemistry and genetics of these organisms which directly or indirectly benefit the plants in nutrient supply, crop production and protection and maintenance of soil fertility. The Book "Biotechnological Approaches in Soil Microorganisms for Sustainable Crop Production" is a compilation of information on such beneficial soil microorganisms which have been recognised as plant nutrient suppliers, nutrient solubilizers or mobilizers, plant growth promoters, plant health promoters, pathogen suppressors, entomopathogens, rhizosphere colonizers, pesticide degraders, pollutant detoxifiers and organic matter decomposers.

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ISBN : 81-7233- [illegible]

JA # 1855

6

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1. INTRODUCTION

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Although many genera and species of N_2-fixing bacteria are isolated from the rhizosphere of various cereals, mainly members of *Azotobacter* and *Azospirillum* genera have been widely tested to increase yields of cereals under field conditions. These bacteria are stimulated in the rhizosphere of cereal crops and a selection for particular type of bacteria also occur in the root zone. Azospirilla and azotobacters are active N_2 fixers under laboratory conditions, generally found wherever these are sought and can use a variety of carbon and energy sources for their growth on combined N or N_2 (8).

A survey of 200 fields in the traditional sorghum and millet-growing areas in North-Western India showed the most probable number (MPN) of N_2 fixers varying from $10^2 - 10^5$ g^{-1} soil. Out of 3760 isolates obtained from these soils following MPN and dilution plate count technique, 42% isolates showed N_2ase activity *in vitro* (6). In another study out of 546 different isolates obtained from the rhizosphere of pearl millet grown at ICRISAT Center, only 17% isolates showed N_2 are activity *in vitro*. Pearl millet rhizosphere was dominated by azospirilla, constituting 72% of total N_2-fixing isolates followed by enterobacters (12%), azotobacters (11%) and puseudomonads (5%) (15).

It is commonly thought that these bacteria could be exploited to increase crop yields through increased BNF. To increase crop yields, the route of artificial inoculation of plants with N_2- fixing bacteria has been tried. Many experiments have been performed in several countries to investigate the effects of inoculation of various strains of *Azotobacter chroococcum* and *Azospirillum* spp. on cereals and grasses. Several field experiments in Belgium, Brazil, Czechoslovakia, Egypt, Israel, India, Germany, Poland, USA and erstwhile USSR with different crops, inoculated with different N_2-fixing bacteria, showed increased yields and / or increased N accumulation by plants, and sometimes resulted in decreased yields because of inoculation.

In this article, the results of several field inoculation trials with azospirilla and azotobacters, mechanisms of increasing crop yields and the extent of BNF's contribution to sustainable agriculture are reviewed. Recent developments in the area of non-legume N_2-fixation are also discussed.

2. CROP RESPONSES TO INOCULATION

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Wani (8) reviewed the comprehensive data obtained from field experiments conducted in erstwhile USSR which showed that out of 1095 experiments, 890 (81%) experiments showed increases in yields of cereals and vegetables and the increases amounted to 10% in only 514 (47%) experiments. Similarly, several subsequent field experiments showed increased crop yields due to *Azotobacter* inoculation (Table 1). In the Estonian S.S R. region, results of 117 field experiments on the use of *Azotobacter* demonstrated that *Azotobacter* is effective only in soil with a native *Azotobacter* population. This observation looks strange since it is generally thought that inoculation is successful in soils that have very low or no population of the inoculant bacteria. Further, it was suggested that instead of *Azotobacter* inoculation it would be more convenient to enhance the growth of the native *Azotobacter* population in the soil by treating seeds with trace elements and other growth factors (18). In Australia, out of 71 field trials with *Azotobacter* inoculation of wheat, in 28 trials grain yields increased by 5%, in 4 trials negative results were observed and in 39 trials no effect on grain yields were observed (19).

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Foxtail millet	2	39.0
Oats	73	12.3
Rye	7	19.1
Millet	9	5.6
Corn	27	10.0

Of late, attention has been shifted from *Azotobacter* to *Azospirillum* as an inoculant as it has widespread distribution in soil, is easy to culture and identify because of its curved form and type of motility, and is relatively efficient in utilization of carbon to support N_2-fixation. In an evaluation of the reported world wide success of *Azotobacter* and *Azospirillum* inoculation, it was concluded that

statistically significant yield increases were obtained in approximately 60% of the trails in erstwhile USSR, Israel and India (8). Mean grain yield of pearl millet increased significantly (up to 33%) due to inoculation with N_2-fixing bacteria over the respective noninoculated controls in 14 out of 24 field experiments (Table 2). In one experiment with *A. lipoferum* and two experiments with *A. chroococcum* no response was observed. In two other experiments grain yields decreased by 2.7% after inoculation with *A. lipoferum* and by 4.5% after inoculation with *A. chroococcum*. Field experiments at ICRISAT Asia Center (IAC) with sorghum showed that inoculation with *Azospirillum* and *Azotobacter* increased the grain yields marginally over the uninoculated control. In a field trial on an Alfisol with three sorghum hybrids CSH 1, CSH 5, and CSH 9, inoculated with *Azospirillum lipoferum* and *A. chroococcum* grain yield was marginally increased by 6% over the control because of inoculation (5). Another trial with three sorghum cvs CSH 5, CSH 9, and SPV 351 and 10 inoculation treatments showed only marginal increase (2 - 10%) in grain and plant dry matter yield across the cvs because of inoculation with N_2-fixing bacteria over the uninoculated control (6). Several field trials with different crops inoculated with azotobacters and azospirilla reviewed by Wani (8) indicated that pearl millet and sorghum which are grown as dryland crops showed 11 - 12% increased yields due to inoculations. Maize, wheat and rice, which receive better management and inputs than pearl millet and sorghum showed 15 - 20% increased yields due to inoculation.

In Israel, field inoculation experiments with *Azospirillum* were carried out using different cereal crops, varieties, and different fertilization levels (23). These experiments were conducted on large plots (200 - 1000 m^2) with 4 - 6 replications and the agronomic practices used were identical to those used for commercial production. Thirty-one such field experiments were conducted and in most cases, the effect of *Azospirillum* varied with the seasons, years, and the crop (Table 3). In general, inoculation of the C-4 plants corn, sorghum, *Panicum*, and *Setaria* showd greater yield increases than the inoculated spring wheat, a C-3 plant. With the summer crops, 75% of the experiments showed significant increases and 90% of the experiments showed increases >5%. The optimum temperature for *Azospirillum* growth is 32 - 35°C and it is possible that bacterial activity, including BNF was greater in the summer, particularly in irrigated crops. During vegetative phase of wheat growth, the soil temperatures in Israel are 10 - 15°C; nevertheless, inoculation of wheat with *Azospirillum* also showed significant increases in foliage and grain yield with lower increases than the summer crops.

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Soil and fertilizer N affect the response to inoculation. Largest differences in yields are obtained when the soil is adequately but not excessively fertilized. In a multi-location experiments with pearl millet, higher increases in grain, plant biomass, and total N uptake were observed with zero N + inoculation and the extent of response declined with the increasing levels of applied N (Table 4). In another set of experiments conducted at four locations in India with pearl millet over five years it was observed that the maximum benefits of inoculation was seen either at 0 or 10 kg N ha^{-1} application than with 20 or 40 kg N ha^{-1} application (30). Grain yields obtained from zero N treatments inoculated with N_2-fixing bacteria were similar to the yields from the non-inoculated plots receiving 20 kg N ha^{-1}. It is therefore not uncommon to observe yield increases equivalent to 20 kg N ha^{-1} depending on locations, soil fertility and other factors (8).

Table 4. Mean grain, total plant biomass yield and total plant N uptake by pearl millet inoculated with N_2-fixing bacteria with different N levels (20).

levels ; ha^{-1})	Bacterial culture: *A. lipoferum*	Bacterial culture: *A. chroococcum*	uninoculated control	Mean	SE ±
	Grain yield (t ha^{-1})*, mean of 7 locations				
	1.8(16)*	1.8(16)	1.5	1.7	
	2.0(10)	1.9(4)	1.8	1.9	0.059 NS
	2.0(6)	2.0(3)	1.9	2.0	
ean	1.93	1 88	1.76		0.033*
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√		20			
	Total plant N uptake (kg ha^{-1}), mean of 2 locations				
0	32.2(27)	29.9(18)	25.3	29.1	
20	37.0(13)	36.6(12)	32.6	35.4	
40	39.2(8)	37.3(3)	36.2	37.6	
Mean	36.1	34.6	31.4		

P = 0.01, NS = Nonsignificant.
Figures in parentheses indicate % increase over controls.

5. ORGANIC MANURES AND INOCULATIONS

Nitrogen-fixing bacteria associated with non-legumes require carbon for their growth and activity in soil. Addition of organic substances introduced into the low organic matter containing tropical soils serve as carbon source for N_2-fixing bacteria and also help the bacteria to overcome the antagonistic effect of soil microflora. Increased nitrogenase activity was observed in the soil when straw was incorporated and the activity enhanced further under warm and moist conditions (31). Similarly, addition of 3% w/w farmyard manure to sand considerably enhanced nitrogenase activity associated with sorghum and millet roots (32). Incorporation of straw (5% w/w) into Nile Delta Soil together with *Azospirillum* inoculation increased dry matter, nitrogen content, and plant height of 12-week old maize plants. Nitrogenase activity associated with corn roots was also increased (33). The inoculation experiment

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Figures in parentheses indicate % increase over controls.

5. ORGANIC MANURES AND INOCULATIONS

Nitrogen-fixing bacteria associated with non-legumes require carbon for their growth and activity in soil. Addition of organic substances introduced into the low organic matter containing tropical soils serve as carbon source for N_2-fixing bacteria and also help the bacteria to overcome the antagonistic effect of soil microflora. Increased nitrogenase activity was observed in the soil when straw was incorporated and the activity enhanced further under warm and moist conditions (31). Similarly, addition of 3% w/w farmyard manure to sand considerably enhanced nitrogenase activity associated with sorghum and millet roots (32). Incorporation of straw (5% w/w) into Nile Delta Soil together with *Azospirillum* inoculation increased dry matter, nitrogen content, and plant height of 12-week old maize plants. Nitrogenase activity associated with corn roots was also increased (33). The inoculation experiment conducted for 2 years in the same plot with pearl millet showed that addition of FYM at 5 t ha^{-1} increased the yield over no FYM plot and further inoculation with *A. lipoferum* or *A. chroococcum* along with FYM increased the yields by 9% and 12% over the FYM alone treatment (26). In field studies, inoculation of rice with *Azotobacter* along with green manuring with *Sesbania*, *Glyricidia*, or *Sunnhemp*, and addition of paddy straw, increased grain yield by 9 - 19% and straw yield by 7-21% over uninoculated controls (34).

6. INTERACTION BETWEEN N_2-FIXING BACTERIA AND OTHER MICROORGANISMS

For simultaneous application of two or more biofertilizers to promote plant nutrition, interactions between N_2-fixing bacteria and other beneficial microorganisms like cellulose decomposers, phosphate solubilizers and mycorrhizae have been studied. Simultaneous application of *A. chroococcum* and *B. polymyxa* performed better at 80 and 100 kg N ha^{-1} (with 9% increase above uninoculated control) than at 120 and 160 kg ha^{-1} (with marginal reduction) (35). Simultaneous inoculation of barley with *A. chroococcum* and *A. brasilense* increased grain yield by 19% over uninoculated control as compared to increases of 9% by *A. chroococcum* and 4% by *A. brasilense* inoculation (36).

In a field experiment, simultaneous inoculation of sorghum with *A. brasilense* and *Glomus fasiculatum* (Vesicular- arbuscular mycorrhizal fungus) showed significant ($P = < 0.05$) increase in grain and fodder yield over uninoculated control and single inoculation with either *A. brasilense* or *G. fasiculatum* (30). The entry of *Acetobacter diazotrophicus* into sugarcane/sweet sorghum roots is facilitated by VA mycorrhzia (37).

7. MECHANISMS OF RESPONSE

Azospirillum, and *Azotobacter* species initially selected for inoculation experiments because of their N_2-fixing ability and close association with plant roots. The mechanisms by which the plants inoculated with these bacteria derive positive benefits in terms of increased grain, plant biomass and N uptake are attributed to small increase in N input from fixation, development and branching of roots, production of plant growth hormones, enhancement in uptake

of NO^{-}_3, NH^{+}_4, PO_4^{3-}, K^+, Rb^+ and Fe^{2+} and improved water status of the plants. In certain experiments high nitrogenase activities (1000 to 3000 nmol C_2H_4 h^{-1} g^{-1} of dry roots) have been observed in case of inoculated plants (28, 33) which could account for total N gains by inoculated plants. However, as nitrogenase activities are one time measurements, such results cannot be extra polated confidently over the whole season. In several experiments even at flowering stage when nitroganese activity is at peak, the activity recorded is low for inoculated plants which could not explain the N gains (16, 22). In trials with pearl millet inoculated with N_2-fixing bacteria, nitrogenase activity increased in field but such increased activity was observed only during later stages of plant gowth for a shorter period. As most of the N required for plant growth in pearl millet and sorghum is taken up before flowering and increased nitrogenase activity was observed after flowering for a short period, the increased activity may not account solely for the increased N uptake observed (22). Pearl millet and sorghum grown in tubes containing either agar medium or sand : FYM or an Alfisol and inoculated with *A. lipoferum* and *A. chroococcum* showed increased root development, more lateral roots and also more root hairs (5, 16). There is still no direct evidence to support claims that hormonal process take place under field conditions. The separation of the effects on plant growth because of bacterial N_2 fixation from those resulting from hormone production by the bacteria may be achieved using mutants lacking either the ability to fix N_2 or to synthesize hormonal compounds. Inoculation of sorghum with *Azotobacter* and *Azospirillum* resulted in marked decline of shoot fly (*Atherigona soccata* Rond.) damage as compared to uninoculated control (38 - 40). Plants inoculated with *Azospirilla* had increased levels of phenol contents in shoots (38).

8. RECENT ADVANCES IN NON-LEGUME N_2 FIXATION

Recently, several approaches using techniques in the area of molecular biology have raised the hopes that at least some non-leguminous field crops become independent of soil nitrogen (41). A meeting held at the International Rice Research Institute (IRRI) in 1992 assessed the feasibility of nodulation and N_2 fixation in rice (42). Following four major short and long-term approaches to address this problem were identified by the workshop participants :

(a) Improve N supply to rice by achieving the colonization and invasion of rice roots by diazotrophic bacteria including ammonia-excreting strains.

(b) Determine the defence responses of rice to rhizobia/*Frankia* and find ways to circumvent them to lay the foundation for engineering the plant to nodulate in the presence of rhizobia/*Frankia*.

(c) Begin assembling active nitrosenase in rice by identifying or creating barriers to protect the enzyme from oxygen.

(d) Improve understanding of N metabolism in rice; assess and model the impact of N_2 fixation on N, C, and energy budgets of the plant and identify control points where N availability regulates photosynthesis, carbohydrate partitioning and leaf senescence.

Under sterile conditions inoculated *Alcaligenes faecalis* attached themselves to the rice root surface, particularly on root hairs near the axis of lateral root with main root (12). Scanning electron microscopic studies revealed that inoculated cells invaded rice roots through epidermis and colonized intercellular spaces mainly in cortex and secondary xylem tissues. Inoculation of genetically engineered strains of *Alcaligenes faecalis* which constitutively express *nif* A both in pot and field conditions increased rice yield by 5 to 8% and fixed 13 - 20% more N_2 compared to the N_2 fixed by wild-type strain. Sprent and de Faira (43) while studying *Parasponia-Rhizobium*, a non-legume symbiosis emphasised that many accepted dogmas for 'normal' symbioses, for example root hair infection and the release of bacteria from infection threads before they differentiate into N_2-fixing forms are not universal. This suggests that a range of systems need to be studied for exploiting the BNF. Aloysius and Paton (44) explored the concept of artificially establishing symbioses between plants and L-forms of bacteria. L-forms of *Azotobacter*, *Pseudomonas syringae*, *Bacillus polymyxa* and *Bejerinkia indica* were all considered as capable of penetration to plant tissue. Although, no tests for nitrogenase activity were performed, such approaches offer possible means of allowing non-legumes such as cereals to fix their own N.

Formation of nodular structures on nonleguminous field crops by rhizobia promoted by enzymatic cell wall degradation coupled with polythelence glycol has been reported (46, 47). This apparently assists the entry of rhizobia, though, nitrogenase activity in the resulting nodules was barely detectable. *Bradyrhizobium parasponium*

is capable of infecting the roots of oilseed rape without enzyme treatment (46). Nie and his colleagues at Shandong University in China have studied the nodule inducing effect of 2, 4-dichlorophenoxy acetate (2,4-D) on the roots of large number of plant species, including wheat (47). This approach resulted from an initial observation by Nie while using plant tissue culture medium containing, 2,4-D. These nodules formed irrespective of whether the roots were inoculated with rhizobia or not. Kennedy *et al.* (48) termed such nodules formed by 2,4-D treatment as para-nodules (para = beyond) to emphasize their distinctness from legume nodules. Rhizobia were found to have the ability to attach themselves to rice roots (49). Nodulation of rice has also been achieved at low frequencies by applying rhizobia either to normal roots (50) or to enzyme-treated roots in the presence of polythene glycol and calcium chloride (46). Using 2,4-D treatment of wheat and *Azospirillum* as microsymbiont, encouraging results have been obtained in this new model of a N_2-fixing symbiosis in non-legumes (51). Substantial rates of ethylene production by the plant seedling treated with 2,4-D however has been reported in absence of both C_2H_2 and azospirilla. Under sterilized conditions ammonia excreting *A. brasilense* colonized 2,4-D induced para- nodules in maize roots, and the nitrogenase activity inside the para-nodules was less sensitive to oxygen than in non- para-nodulating roots (52). If this *in-vitro* model can be shown to be a working systems in the field, application of para- nodulation in agricultural crops require further studies. It is not known whether the introduced diazotrophs can selectively colonize para-nodules (52). However, we need to answer several questions for example : (i) Is there a direct transfer of fixed nitrogen to the host plant, or is fixation simply bound to the growth of *Azospirillum* ? (ii) What will be the carbon costs to plants for sustaining para-nodules? (iii) how long the para- nodules will remain as active sites of nitrogen fixation? (iv) Is the oxygen requirement of N_2 fixation likely to be satisfied in para-nodules ? etc. Further, the agricultural use of 2,4-D is discouraged because of toxicity and slow degradability. In a recent paper Ladha and Reddy (52) have elaborately discussed the necessity and possibilities for extension of nitrogen fixation to rice and opined that presently there are many potential obstacles to the development of BNF capability in rice through nodulation or *nif* gene transfer. At the moment, urgent need is to identify stable and effective endophytic diazotroph for rice.

Plant pathogenic bacteria *Agrobactetium tumefaciens* (54) and *Pseudomonas rubrisubalbicans* (55) causing mottled stripe disease in sugarcane were able to fix molecular nitrogen. Whether such bacteria could be exploited for beneficial roles, rather than their destructive abilitiés, require exploration.

9. FUTURE NEEDS

While the progress through use of methods used in biotechnology may lead to breakthroughs in due course, concerted efforts through conventional microbiological techniques will have to be put towards understanding the complex systems. Such studies will enable to identify stable and effective endophytic associations like *Acetobacter diazotrophicus* in sugarcane contributing positive N balance with other nonlegumes. Further, very little is known about the competitiveness of microorganisms and the factors governing it. Research is needed in soil physical and chemical factors that influence both the establishment in the rhizosphere and the expression of its traits fully for benefiting the crop. Once these factors are identified, it may be possible to manipulate them in the field so as to enhance the consistency of their performance. There is need to study the reasons for decline in the numbers of inoculated bacteria (8) and to find the agronomic practices that may help to establish the inoculated bacteria in large numbers in the rhizosphere. The potential for strain selection for cops does exist. However, the criteria for strain selection need to be changed looking into the results of the response mechanisms. Research to understand the mechanisms by which the introduced microorganisms benefit the crop is critically important. Identifying important traits would enable efficient selection of new strains. Efficient strains with selective traits to perform well under adverse conditions like soil salinity, moisture stress, need to be selected or developed and tested for their performance.

More research on formulation and efficient delivery of the biofertilisers is needed. Search for newer synthetic carrier materials which can be uniform, non-toxic, simple to use and support large populations of introduced microorganisms for a longer time must be pursued vigorously.

10. CONCLUSIONS

In order to reach the estimated target of 240 million tonnes of

microbes through BNF or improved fertilizer use efficiency. Comprehensive reviews on non-symbiotic/ associative N_2-fixing bacteria have shown 60% of occurrence of success with statistically significant increases in yield up to 30% due to inoculations. On an average dryland crops such as pearl millet and sorghum show 10 - 12% increase in yields and maize, wheat, and rice grown with better management and inputs show 15 - 20% increase in yields over uninoculated control due to inoculation with N_2-fixing bacteria. In India sorghum is gown over 12.9 million ha with an average production of 900 kg ha^{-1}, pearl millet on 9.5 million ha with 530 kg ha^{-1} average yield, rice on 42 million ha with 1880 kg ha^{-1} grain yield, wheat on 24.9 million ha with 2370 kg ha^{-1} grain yield and maize on 5.9 million ha with 670 kg ha^{-1} average grain yield (56). Assuming that inoculation with N_2-fixing bacteria increases the yield by 10% on 50% of the area sown with sorghum, pearl millet, rice, wheat and maize in India, the increased yields would be about 0.57 million tonnes for sorghum, 0.25 million tonnes for pearl millet, 3.9 million tonnes for rice, 2.9 million tonnes for wheat and 0.47 million tonnes for maize. How much of such increased yields are due to increased BNF, due to increased N uptake or increased N use efficiency by plants is an academic question. However, to cover such a large area with "good quality" bacterial inoculants is not an easy task. Estimated requirement of biofertilizers (excluding blue green algae) is 84,800 tonnes per year for India (57). It is an important task to ensure supply of such a large quantity of biofertilizers to farmers in India as availability of "good quality" inoculants has been identified as one of the important constraints responsible for successful use of BNF technology (58). For success of biofertilizers in countries like India, concerted efforts right from production, demonstration to distribution are needed. The next step is convincing and educating the farmers regarding the benefits of these inoculants for sustaining productivity of our soils. In many cases the increases are smaller (for eg. 50 to 230 kg ha^{-1} in different crops @ 10% an average increase) than the changes in yield due to climatic and biotic (diseases insects) variations. In cases where enough soil N is available for crop yield the yields may not increase but less soil N would be utilized for producing same yield. There is a need to demonstrate the benefits from BNF technology in terms of maintenance or improvement of soil fertility through long-term experiments. In case of biofertilizers consistent benefits in terms of appreciable increase in economic crop yields are not observed by farmers due to the factors mentioned above. In such a case government/society has to take action for maintaining the soil resource, as is the case of soil and water conservation practices. Along with the use of good quality biofertilizers, optimum management practices need to be provided to ensure maximum contribution from the BNF. In the tropics plant residues are not generally incorporated in soil. There is need to generate plant material on farm (eg. growing legumes like *Sesbania* and *Glyrecidia* on farm bunds, growing short duration crops after harvesting of main crop etc.) for incorporation in soil. Such incorporation would enhance the nonsymbiotic N_2-fixation associated with microbial degradation of the residues which would help in improving the soil fertility status and also to serve as the carbon source for rhizosphere activity of the inoculated bacteria. A holistic approach to harness the benefits from N_2-fixing bacteria associated with nonlegumes is needed.

ACKNOWLEDGEMENT

Mr. P.N. Murthy's wordprocessing assistance is acknowledged.

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10. CONCLUSIONS

In order to reach the estimated target of 240 million tonnes of

microbes through BNF or improved fertilizer use efficiency. Comprehensive reviews on non-symbiotic/ associative N_2-fixing bacteria have shown 60% of occurrence of success with statistically significant increases in yield up to 30% due to inoculations. On an average dryland crops such as pearl millet and sorghum show 10 - 12% increase in yields and maize, wheat, and rice grown with better management and inputs show 15 - 20% increase in yields over uninoculated control due to inoculation with N_2-fixing bacteria. In India sorghum is gown over 12.9 million ha with an average production of 900 kg ha^{-1}, pearl millet on 9.5 million ha with 530 kg ha^{-1} average yield, rice on 42 million ha with 1880 kg ha^{-1} grain yield, wheat on 24.9 million ha with 2370 kg ha^{-1} grain yield and maize on 5.9 million ha with 670 kg ha^{-1} average grain yield (56). Assuming that inoculation with N_2-fixing bacteria increases the yield by 10% on 50% of the area sown with sorghum, pearl millet, rice, wheat and maize in India, the increased yields would be about 0.57 million tonnes for sorghum, 0.25 million tonnes for pearl millet, 3.9 million tonnes for rice, 2.9 million tonnes for wheat and 0.47 million tonnes for maize. How much of such increased yields are due to increased BNF, due to increased N uptake or increased N use efficiency by plants is an academic question. However, to cover such a large area with "good quality" bacterial inoculants is not an easy task. Estimated requirement of biofertilizers (excluding blue green algae) is 84,800 tonnes per year for India (57). It is an important task to ensure supply of such a large quantity of biofertilizers to farmers in India as availability of "good quality" inoculants has been identified as one of the important constraints responsible for successful use of BNF technology (58). For success of biofertilizers in countries like India, concerted efforts right from production, demonstration to distribution are needed. The next step is convincing and educating the farmers regarding the benefits of these inoculants for sustaining productivity of our soils. In many cases the increases are smaller (for eg. 50 to 230 kg ha^{-1} in different crops @ 10% an average increase) than the changes in yield due to climatic and biotic (diseases insects) variations. In cases where enough soil N is available for crop yield the yields may not increase but less soil N would be utilized for producing same yield. There is a need to demonstrate the benefits from BNF technology in terms of maintenance or improvement of soil fertility through long-term experiments. In case of biofertilizers consistent benefits in terms of appreciable increase in economic crop yields are not observed by farmers due to the factors mentioned above. In such a case government/society has to take action for maintaining the soil resource, as is the case of soil and water conservation practices. Along with the use of good quality biofertilizers, optimum management practices need to be provided to ensure maximum contribution from the BNF. In the tropics plant residues are not generally incorporated in soil. There is need to generate plant material on farm (eg. growing legumes like *Sesbania* and *Glyrecidia* on farm bunds, growing short duration crops after harvesting of main crop etc.) for incorporation in soil. Such incorporation would enhance the nonsymbiotic N_2-fixation associated with microbial degradation of the residues which would help in improving the soil fertility status and also to serve as the carbon source for rhizosphere activity of the inoculated bacteria. A holistic approach to harness the benefits from N_2-fixing bacteria associated with nonlegumes is needed.

ACKNOWLEDGEMENT

Mr. P.N. Murthy's wordprocessing assistance is acknowledged.

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