DISCUSSION
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Creating public understanding of science in an era when science and technology are permeating every fabric of society needs no emphasis. Though we boast of having the third largest pool of scientific and technological manpower in the world, there is much to be done in the field of science and technology, particularly S & T communication. Despite some encouraging trends in recent years, the readily available media friendly Western stuff gets the best treatment in our communication media.

S & T have been an integral part of the Indian tradition since time immemorial, dating back several millennia, in fact, for as long as 4000 to 5000 years preceding the ‘industrial revolution’. India was always in the forefront as far as contemporary scientific knowledge and its understanding was concerned. It was, however, only after independence, and through the vision and wholehearted support of India’s first Prime Minister Jawaharlal Nehru, that S & T were developed in a conscious way as a major force for social and economic change. Even our constitution’s “Article 51 (A) (h) clearly states”...to develop scientific temper, humanism and the spirit of enquiry and reforms”. It seeks that science must permeate the whole of our national life and all areas of endeavour. The development of S & T as a means to meet vital national needs is now accepted as major planning objective as is evident from the Science and Technology Policy 2003, especially C 12 of the S & T Policy
2003: Public awareness of science and technology. The total annual expenditure on research and development (R & D) was 0.81 per cent of the gross national product (GNP) during 1998-99. As on April 1, 1998, the number of personnel employed in R & D establishments was 3.08 lac. Underpinning a host of major efforts in the areas of applied S & T is a wide ranging programme of basic research carried out in the educational institutions and national laboratories of the country. Presently there are a number of university level institutions (Association of Indian Universities Members) in India (including 60 deemed universities). Of these, 119 are traditional universities (including 32 institutions for specialized studies in disciplines) which the other is professional/technical institutions. 39 institutions provide education in agriculture (including forestry, dairy, fisheries, and veterinary science), 16 in health sciences, 38 in engineering & technology, 4 in information technology, 1 in journalism, 4 in law and 10 are open universities. The tremendous growth in organized science of the post-independence era is quite impressive with 545 central government run R & D institutions including public sector undertakings (Jain, 2006).

Man began to cultivate land in an organized way for food grains around 8000 B.C. Very soon, he learned that the same land can not support the growth of plants endlessly and this led him to think about the ways and means of improving the fertility of soil.

The modern day intensive crop cultivation requires the use of chemical fertilizers are not only in short supply but also expensive in
developing countries. Therefore, the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones, more particularly biofertilizers of microbial origin. Microbial processes are not only quick, but consume relatively less energy than industrial processes. Secondly, they have the advantage of being diversified into small units to meet the demands of the specific problems of location, which one is apt to come across in the agricultural practice of nation, and which have not taken to mechanization of farming. A small or a marginal farmer has to be educated on the ways and means of recycling farm wastes. In soil, myriads of micro-organisms are at work in fixing nitrogen, mobilizing other plant nutrients and degrading ligno-cellulosic wastes. Very often, micro-organisms are not as efficient in natural surroundings as one would expect them to be and therefore, artificially multiplied cultures of selected micro-organisms play a part in accelerating nature's way of recycling organic resources.

Rice is the major food crop in South and South East Asia and covers an area of about 36 million hectares in India. Until mid 1960's, rice yields in India were generally low and in the face of increasing population pressure, the future was looked upon with a feeling of profound concern. However, during the past decade, scientific developments have shown that tropical rice yields could be raised several fold and within a short period, some rice growing countries have converted chronic deficits into self-sufficiency by the application of new production technology. The rate of growth in production established now will, however, be sustained only if effective investments are ploughed in. In other words, a fall in production, if it occurs in future, will be
less from technological weaknesses than from neglected opportunities.

Competition for space and resources has imposed on us the necessity to further optimize our exploitation of cultivated and wild lands. Furthermore, new dimensions are being added to such problems at an increasing rate. Economic constraints change rapidly as modern technology introduces new tools and materials, new distribution pattern for products and increased availability of input like water, fertilizer and improved genetic materials. An important problem is not only to increase the yield per unit area, but also per unit input.

In areas of intensive agriculture, it is now economically possible or at least feasible to provide most of a crop’s nitrogen needs in the form of chemically produced fertilizer input. In other areas much of the total nitrogen and organic matter is a product of many eco-system variables and climatic factors. Thus the question is, what is the system’s optimum balance in terms of nitrogen as well as energy? To understand the ecosystem economy we need systems analysis. Elucidation of the major nitrogen inputs and outputs of the ecosystem, estimation of microbial transformations and internal nitrogen turnover and extensive application of low-cost nitrogen fertilizer are aspects of the nitrogen economy that still require study. Similarly, the deficits in balance sheets (Allison, 1955), nitrate contamination of ground-water supplies and the changing status of carbon nitrogen relationships need special attention. The resulting turnover fractions for any given income rate will regulate both the availability and the ultimate reserves of nitrogen (Dahlman et al., 1969).
Rice is an exclusive crop plant of aquatic habitat, largely raised in an anaerobic or partially anaerobic submerged environment. The most important characteristic of a submerged soil is the existence of a layer of standing water, which exercises a profound influence on the physico-chemical and biological conditions of the soil below. The important physical changes brought about by inundation are gaseous exchanges, reaction, specific conductance and redox potential. The chemical properties which undergo changes on submergence are essentially the complex transformations of various elements. These depend on factors like the redox potential, pH, nature and quantity of organic matter, base status of the soil and microbiological activity.

The principal biological consequences of water logging are the suppression of changes of mesophytic vegetation in soil microflora and the growth of several forms of algae. The growth and activity of algae in submerged soil, some of which possessing efficient systems for fixing atmospheric nitrogen, are widely recognized in tropical rice field soil. The photoautotrophic habit of these organisms and their luxurious growth in aquatic environments explain their agricultural and ecological importance.

Nineteen seventies was the decade that witnessed escalating petroleum crisis, thereby enormously increasing the organic fertilizer prices. To mitigate the problem, biologists came out with biological substitutes to organic fertilizers – the so called ‘BIOFERTILIZERS’

The term ‘Biofertilizers’ or more appropriately called ‘microbial
inoculants' can be generally defined as preparations containing live or latent cells of efficient stains of nitrogen – fixing, phosphate- solubilizing, or cellulolytic micro-organisms used for application to seed, soil, or composting areas with the objective of increasing the members of such micro-organisms and accelerating certain microbial processes to easily assimilated by plants. In a larger sence, the term may be use to include all organic resources (manures) for plant growth which are rendered in an available form for plant absorption through micro-organisms or micro-organisms plant associations or interactions. Such microbiological processes may be as complex as that of nitrogenase mediated reactions in nitrogen-fixing micro-organisms which reduce elemental nitrogen into ammonia or as simple as the organic acid secretion by phosphate dissolving bacteria. Biofertilizer is the term to denote all the nutrients input of biological origin that serves as manure for crop plants.

The requirement of crop plants for ammonia has been largely met by industrial production through ‘Haber Bosch’ process. This process involves much expenditure by way of hydrogen production, installation of industrial complex at a suitable locality and finally transport of the fertilizer to the place of need. In addition, it releases harmful pollutants into atmosphere causing serious health hazards to human being. One of the alternatives to chemical fertilizers is the efficient use of microorganisms as 'biofertilizers'.

Rice (*Oryza sativa*) is largely grown in wetland conditions with a layer of *saliva*. The flooded rice plant ecosystem is extremely complex,
chemically, and microbiologically. One of the effects of flooding in uncropped rice field is a fall in $O_2$ content. However, in rice-cropped soil, due to aerenchyma in the rice plant, $O_2$ is capable of moving from the leaf blade to the root cortex. This results in the oxidation of soil around the actively growing root system. Flooding of soil results in ammonium accumulation and nitrate instability. Ammonical nitrogen, the dominant form of mineral nitrogen in lowland rice soil, is liable to fixation by clay, loss by volatilization, nitrification, denitrification, leaching, runoff and seepage. About 60-80 per cent of nitrogen absorbed by crops (40-50 kg N/ha) can be attributed to the native nitrogen pool. Approximately 60 per cent of the rice yields (2-4 t/ha) can be obtained without the application of nitrogen fertilizer. The soil nitrogen does not show decreasing trends by rice planting and harvest, indicating the existence of biological mechanisms to renew the depleted nitrogen from the soil nitrogen pool. Legumes, Azolla, nitrogen fixing bacteria, and blue green algae take part in biological fixation of nitrogen. The fixed nitrogen is mostly mineralized to $NH_4^+$ which is the key process of nitrogen nutrition in waterlogged soil which is subjected to environmental stresses (Roger and Watanabe, 1986; DE Datta, 1987).

Analysis of the blue green algal flora from rice fields has revealed the occurrence of species of Anabaena, Anabaenopsis, Aulosira, Cylindrospermum, Nostoc, Calothrix Stigconema, Westiella, Westiellopsis, Campylonema and Microchaete as dominant nitrogen fixers. Besides fixing nitrogen, these algae excrete vitamin $B_{12}$, auxins, and ascorbic acid which may also contribute to the growth of rice plants (Dee, 1939; Singh, 1961; Stewart, 1970, 1971, 1974).
The idea of inoculation of biofertilizer was indirectly known to our ancestors when they transferred large amounts of soil from areas where leguminous crops were flourishing to areas where they were less luxuriant. In a sense, they were inoculating nodule forming bacteria from one field to another. With the advent of an energy crisis, non-symbiotic nitrogen fixing micro-organisms got their due emphasis and applied research took shape in developing countries. Nitrogen fixing bacteria and blue green algae and aquatic *Azolla* containing nitrogen fixing blue green alga (*Azolla anabaena*) were highlighted.

According to Singh (1999), blue green algae (BGA) constitute a group of aquatic microorganisms which have all the time fascinated the scientist because they are the only prokaryotes performing oxygenic photosynthesis. Since no sexual reproduction has yet been demonstrated among BGA, their traditional classification is entirely based upon morphological features with some reference to their ecological distribution. The divergence of opinion which has resulted from the morphological criteria is enormous and has led to an inflated number of species because in early years a single character difference was thought sufficient to separate a new species from one previously described. Isolated strains should be described only after growing them under standardized conditions of medium light intensity and temperature.

Interest in BGA arises mainly from:

(a) the ability of number of genera to fix atmospheric nitrogen which has implications in the maintenance of soil fertility especially in rice fields,
(b) the high nitrogen content of some genera especially *Spirulina*, and the possible uses of certain strains as food or feed,

(c) the possible use of BGA as a source of useful biochemicals,

(d) and the last but not the least, the academic curiosity for the most diverse and widely distributed group of photosynthetic prokaryotes.

The ambivalent taxonomic position of BGA has been a hinderance for undertaking the extensive experimental work. On the basis of the extensive work conducted at the Pasteur Institute in Paris, Singh (1999) emphasized the prokaryotic nature of BGA and stated that ‘the logical treatment of the cyanobacteria (BGA) was to place them in super kingdom prokaryotae as a division, class or order of bacteria’.

Blue green algae play a role in the nitrogen economy of tropical rice soils (Dee, 1939; Singh, 1961). The nitrogen fixing algae can be cultured in open airtanks and used for rice cultivation. The results obtained by algal inoculation of rice fields in India have shown the possibility of using algae as biofertilizer in rice cultivation. Singh (1961), Dadhich *et al.* (1969), Cole (1977), Kulasooriya and Silva (1978), Agarwal (1979), Rodgers *et al.* (1979), Roger and Kulasooriya (1980), Goyal (1982), Kulasooriya *et al.* (1982), Roger *et al.* (1985), Grant *et al.* (1985), Singh and Bisoyi (1989), Roy *et al.* (1990), Santra (1990), Mandhave *et al.* (1990), Ahluwalia *et al.* (1990), Pachapande (1990), Gulati (1990), Kannaiyan and Subramani (1990), and Bobada *et al.* (1990) with paddy; Rattan (1990) with cotton; and Mohan *et al.* (1990) with linseed, observed encouraging results while using blue green algae as biofertilizers.
Economically, more important is perhaps the potential use of bga as a physiological tool for improving plant growth and increasing yield. Unfortunately, the data available on the effect of bga on metabolism and mineral composition of plants, closely related with yield, food values of plants and their economic importance is very meager to throw sufficient light on the role of bga on plant metabolism and their mineral composition. In view of insufficient evidences and with the line of suggestions of Robinson (1975), Mohan et al. (1980), Mohan (1983) and Katiyar (1991) that the beneficial interaction between growth regulating compounds and fertilizer application levels including biofertilizers may be of practical significance. For a conclusion on the effects of bga as biofertilizer on plant composition, this problem was undertaken.

The increase in dry matter yield of both tops and grains of paddy, stem, leaves and fruits of tomato plants increased with the increase in supply of blue green algae as biofertilizers, upto 200 g per kg level. This increase in growth and yield is in conformity with the findings of Allen and Arnon (1955), Singh (1961), Dadhich et al. (1969), Cole (1977), Rao et al. (1977), Panigrahi and Singh (1978), Agarwal (1979), Rodgers et al. (1979), Roger et al. (1985), Roger and Kulasooriy (1980), Kannaiyan (1982 and 1983), Goyal (1982), Rao (1983), Chandraker et al. (1983), Bhuia et al. (1984), Bongale (1984), Bagal and Patil (1984), Kulasooriy et al. (1984), Ram and Rawat (1984), Grant et al. (1985), Sawabhe et al. (1985), Chandrasekaran (1978), Gupta et al. (1989), Singh and Bisoyi (1989), Ahluwalia et al. (1990), Bobade et al. (1990), Gulati (1990), Mandhave et al.

With BGA application in the range of 150 g to 200 g per kg soil showed maximum values for chlorophyll and ascorbic acid content and catalase and peroxidase activities of both paddy and tomato plants. The increase was found in conformity with the findings of Abd, Alla et al. (1994) for chlorophyll content in wheat and Mohan et al. (1987 and 1989) for chlorophyll and ascorbic acid content, and catalase and peroxidase activities in linseed plants. The increase in ascorbic acid content is not in conformity with the result of Kaushik and Venkataraman (1979) who observed insignificant effect on tomato plant.

Generally, 100 to 200 g blue green algae per kg soil increased the tissue concentration of calcium, potassium, magnesium, phosphorus, sulphur, iron and manganese content of tops and grains of paddy and both
stem and leaves and fruits of tomato plants. This increase in tissue concentration of mineral nutrient elements is in conformity with the earlier findings of Latchumanan et al. (1979) in wheat and Singh et al. (1997) in wheat and rice for potassium and phosphorus content; Mohan et al. (1989) in linseed plant for calcium, potassium, magnesium, sulphur and iron content. The increase in tissue phosphorus is not in conformity with the results of Mohan et al. (1989), who reported insignificant increase in linseed plants.

200 g blue green algae as biofertilizer per kg soil level was found to be the best level of supply for tissue nitrogen in tops and grains of paddy, and both stem and leaves and fruits of tomato. The results are in accordance with the findings of Dachich et al. (1969), Latchumanan et al. (1979), Mohan et al. (1989, 2003, 2004, 2005 and 2006), Gulati (1990), Abd, Alla et al. (1994), Singh et al. (1997) and Kamuru et al. (1998). However, the findings presented in this study is not in accordance with the observations of Rodgers et al. (1979) who observed decrease in total nitrogen of radish leaves when inoculated with algae alone, and general reduction in total nitrogen contents of tomato plants growth on BGA inoculated soil. Kaushik and Venkataraman (1979) has also not observed any significant increase in the nitrogen of the tops of tomato plants.

Maximum value for crude protein content was observed with 200 g blue green algae as BF/kg soil level in tops of both 40 and 100 days old and grains of paddy; and both stem and leaves of both 40 and 100 days paddy plants and in fruits of tomato plants.
Overall, blue green algae as biofertilizer, was found to be the best for qualitative and quantitative improvement of paddy and tomato plants. The above finding for biofertilizer is also supported by the observations made by Agnihotri et al. (2005), Mohan et al. (2003, 2004, 2005, 2006), Singh et al. (2004), Singh and Singh (1983), Singh and Bisoyi (1993), Srivastava et al. (2003) and Pasricha et al. (1996).

It appears that blue green algae increases the mineral uptake in many ways, such as increase in the permeability of cell membrane, influence on metabolic pathways etc. may be due to action of its extracellular products as growth promoting substances.

The energy crisis and consequent increase in the cost of chemical fertilizers, the widening gap between the indigenous supply and demand of nitrogen and the low purchasing power of cultivators have imposed serious limitations in rice productions. Biological nitrogen fixation is being considered as an alternative, at least in part of chemical fertilizers in the global strategy for increasing production of crops.

The adaptation of organic manure as compared to nitrogen fertilizer would be very less expensive, besides being quite safer as compared to chemical fertilizers.

To conclude, blue green algae as biofertilizers may prove efficient tool for boosting green revolution and to overcome food shortage all over the world.