

Promoting Bio-fertilizers in Indian Agriculture

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Abstract

The green revolution brought impressive gains in food production but with insufficient concern for sustainability. In India the availability and affordability of fossil fuel based chemical fertilizers at the farm level have been ensured only through imports and subsidies. Dependence on chemical fertilizers for future agricultural growth would mean further loss in soil quality, possibilities of water contamination and unsustainable burden on the fiscal system. The Government of India has been trying to promote an improved practice involving use of bio-fertilizers along with fertilizers. These inputs have multiple beneficial impacts on the soil and can be relatively cheap and convenient for use. Consistent with current outlook, the government aims not only to encourage their use in agriculture but also to promote private initiative and commercial viability of production. This paper analyses available industry side data to find only a limited extent of success till date. There has been no accelerated growth in distribution with time, inadequate spatial diffusion and despite entry of small private units into the industry there is no clear indication of the success of privatization. The paper however argues that considering the social benefits promised the government has ample grounds to intervene to set up an effective market for the new product while encouraging private players. But the policy and the instruments of intervention need to be designed with care.

Promoting Bio-fertilizers in Indian Agriculture

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Failure of a market to build up calls for public intervention when the expected social gains from a relatively new product outweigh the costs whereas the private gains do not. Uncertainty about the product performance coupled with long periods of learning involved can lead to poor demand from end users who are farmers. Even in the context of market liberalization, the government has some role to play to induce a socially optimal investment level and set up an effective market so long as market information is imperfect. However the exact nature of the role and the policy instruments to be used must be decided with a clear understanding of the strengths and weakness of agents involved (Stiglitz, 1989). Biofertilizers make nutrients that are naturally abundant in soil or atmosphere usable for plants. Field studies have demonstrated them to be effective and cheap inputs, free from the environmentally adverse implications that chemicals have. Biofertilizers offer a new technology to Indian agriculture holding a promise to balance many of the shortcomings of the conventional chemical based technology. It is a product that is likely to be commercially promising in the long run once information becomes available adequately to producers and farmers through experience and communication.

There is an ongoing attempt to promote biofertilizer in Indian agriculture through public intervention, and in keeping with the spirit of the times, the policy motivates private sector and profit motive to propel the new technology. The question raised in this paper is how successful has the intervention policy been in Indian agriculture. The Government of India and the various State Governments have been promoting the nascent biofertilizer market both at the level of the user-farmer and the producer-investor through the following measures: (i) farm level extension and promotion programmes, (ii) financial assistance to investors in setting up units, (iii) subsidies on sales and (iv) direct production in public sector and cooperative organizations and in universities and research institutions. Over time as the industry emerges from infancy with public guidance, the following observations will be expected: (a) increasing sales volumes and diffusion across the country, (b) greater role of profit motivated private enterprise. Since information on farm level usage of biofertilizers or profitability of units are not reported till date, one way to get about is by following the secondary indicators as incorporated in (a) and (b).

5.2 What are Biofertilizers?

Biofertilizers, more commonly known as microbial inoculants, are artificially multiplied cultures of certain soil organisms that can improve soil fertility and crop productivity. Although the

beneficial effects of legumes in improving soil fertility was known since ancient times and their role in biological nitrogen fixation was discovered more than a century ago, commercial exploitation of such biological processes is of recent interest and practice.

The commercial history of biofertilizers began with the launch of 'Nitragin' by Nobbe and Hiltner, a laboratory culture of Rhizobia in 1895, followed by the discovery of Azotobacter and then the blue green algae and a host of other micro-organisms. Azospirillum and Vesicular-Arbuscular Micorrhizae (VAM) are fairly recent discoveries. In India the first study on legume Rhizobium symbiosis was conducted by N.V.Joshi and the first commercial production started as early as 1956. However the Ministry of Agriculture under the Ninth Plan initiated the real effort to popularize and promote the input with the setting up of the National Project on Development and Use of Biofertilizers (NPDB). Commonly explored biofertilizers in India are mentioned below along with some salient features.

Rhizobium (RHZ): These inoculants are known for their ability to fix atmospheric nitrogen in symbiotic association with plants forming nodules in roots (stem nodules in sesabaniamrostrata). RHZ are however limited by their specificity and only certain legumes are benefited from this symbiosis.

Azotobacter (AZT): This has been found beneficial to a wide array of crops covering cereals, millets, vegetables, cotton and sugarcane. It is free living and non-symbiotic nitrogen fixing organism that also produces certain substances good for the growth of plants and antibodies that suppress many root pathogens.

Azospirillum (AZS): This is also a nitrogen-fixing micro organism beneficial for non-leguminous plants. Like AZT, the benefits transcend nitrogen enrichment through production of growth promoting substances.

Blue green Algae (BGA) and Azolla: BGA are photosynthetic nitrogen fixers and are free living. They are found in abundance in India¹. They too add growth-promoting substances including vitamin B12, improve the soil's aeration and water holding capacity and add to bio mass when decomposed after life cycle. Azolla is an aquatic fern found in small and shallow water bodies and in rice fields. It has symbiotic relation with BGA and can help rice or other crops through dual cropping or green manuring of soil.

Phosphate solubilizing (PSB)/Mobilizing biofertilizer: Phosphorus, both native in soil and applied in inorganic fertilizers becomes mostly unavailable to crops because of its low levels of mobility and solubility and its tendency to become fixed in soil. The PSB are life forms that can help in improving phosphate uptake of plants in different ways. The PSB also has the potential to make utilization of India's abundant deposits of rock phosphates possible, much of which is not enriched.

Responses, and Limitations

Crude calculations of bulk and cost in terms of N presented in Table 1 on the basis of reported nitrogen equivalence indicates that biofertilizers are cheap and convenient relative to chemical and farm organic fertilizers (FYM) and therefore have considerable promise for crops like cereals, oilseeds, vegetables and cotton. However, it is safer to note that the nitrogen equivalences reported for biofertilizers are only indirectly approximated through controlled experiments since the way of accessing nutrients itself in indirect unlike nutrient *containing* chemical fertilizers and manures, and the comparative values of bulk and cost may not be realistic. Nevertheless, a crude estimation is attempted for indication of the potential without attaching significance to the magnitudes as such.

Biofertilizers have various benefits. Besides accessing nutrients, for current intake as well as residual, different biofertilizers also provide growth-promoting factors to plants and some have been successfully facilitating composting and effective recycling of solid wastes. By controlling soil borne diseases and improving the soil health and soil properties these organisms help not only in saving, but also in effectively utilising chemical fertilizers and result in higher yield rates.

However while positive responses have been observed in a wide range of field trials, there is remarkable inconsistency in responses across crops, regions and other conditions. Even for a given crop the range of response is quite high. For example in a sample of 411 field trials carried out across districts, plant responses to inoculation with *Azotobacter* in irrigated wheat was observed to be significant in 342 cases and ranged from 34 to 247 Kg./Ha. (Hegde and Dwivedi, 1994). Legume inoculation by *Rhizobium* is the most long established practice but the responses

Table1: Relative Cost of Access to Plant Nutrient (N)						
Crop	Fertilizer Type	Treatment	Inoculant/ unit weight Kg	Price Rs/Kg	For 1 Kg Nitrogen	
					Bulk	Cost

					Weight Kg	Rs/Kg
Biofertilizers						
Rice	AZS	seedling	2.5	29.12	0.13	3.64
Wheat	AZT	seed	1.5	34.37	0.75	2.58
Oilseeds	AZT	seed	0.2	34.37	0.01	0.34
Groundnut/Soyabean	RHZ	seed	1.5	30.89	0.07	2.26
Maize/Sorgum	AZS/AZT	seed	0.5	29.12-34.37	0.025	0.73-0.86
Potato	AZT	soil/tuber	4.5	34.37	0.225	7.73
Vegetables	AZS/AZT	seed	0.5	29.12-34.37	0.25	0.73-0.86
Sugarcane	AZT	soil	4.5	34.37	0.225	7.73
Cotton	AZT	seed	0.8	34.37	0.04	1.37
Flowers	AZS/AZT	seedling	1.75	29.12-34.37	0.09	2.55-3.01
Chemical	Urea	soil	1000	4.8	2.17	7.96
Organic	FYM	soil	1000	0.14	555.56	79.37
Note: Vegetables - radish, spinach and ladyfinger; Oilseeds -Mustard sesamum Flowers - merigold, other seasonal plantation and ornamental plants Nitrogen equivalence of inoc./unit: AZS and AZT -20Kg N and RHZ-19-22Kg N; Urea - 46% N; FYM – 3.6Kg NPK (2:1:1) per Tonne as per FAI. Unit weight of inoculant is as recommended dosage. Important: The comparisons with Biofertilizers are only indicative as quantitative values are only approximations.						
Source: Computation based FAI figures.						

indicated by the All India Coordinated Agronomic Research Project in the cases of mungbean, uradbean, soyabean, cowpea and groundnut all under irrigated condition were significant only in a small proportion of locations tried and failed in others. Residual effect on soil pool was not noted in most cases. The variance of responses is similar for AZT and AZS. Dryland agriculture constitutes a very large part of agricultural area in India and also houses the majority of the poor. More than 90% of coarse cereals, 80% of groundnut and 85% of pulses come from these regions. Low productivity, unpredictable climatic swings and low dosage of chemical fertilizers also characterise agriculture in drylands. Biofertilizers, particularly Rhizobium, could be a bridge between removals and additions to soil nutrients where farmers can scarcely afford costly inputs and that too in a risky environment. But consistency in gains again eludes the trials conducted by All India Coordinated Pulse Improvement Project.

The responses usually depend on several environmental factors. (a) The type of soil as measured by its water holding capacity, its levels of other nitrates, phosphate and even calcium and molybdenum (that help in protein synthesis in Rhyzobia) and the alkalinity, salinity and acidity of soil all affect the response. Higher dose of mineral nitrogen as starter suppresses nodulation, reducing response of Rhyzobium but phosphate deficiency can be an inhibitor also. (b) The inadequacy of organic matter especially common in dryland agriculture is a deterrent more for the non-symbiotic strains, which essentially depend on soil organic matter for energy.

Phosphobactrin response was found to be positive only in soils with high organic content and low available phosphorous. (c) Soil water deficit and high temperature (hyper-thermia) are prominent abiotic factors that affect nitrogen fixation in dryland agriculture. (c) Native microbial population opposes the inoculants. In general predatory organisms, often already present in the soil are more adapted to the environment and out compete the inoculated population.

Apart from environmental factors, deficiencies in handling procedure are a major cause of under performance in real life application. The high sensitivity to temperature and other external conditions of these 'living' inputs, calls for enormous caution at the stage of manufacture/culture, transportation/distribution and application. This involves investment and time in research (for more tolerant strains), packaging, storage and use of suitable carrier materials.

5.3 Government Intervention in Biofertilizer Market

To attain production targets, the Government of India implemented a central sector scheme called National Project on Development and use of Biofertilizers (NPDB) during the Ninth Plan for the production, distribution and promotion of biofertilizers. A National Biofertilizer Development Centre was established at Ghaziabad as a subordinate office of the Department of Agriculture and Cooperation with six regional centers. The purpose of the scheme covered organization of training courses for extension workers and field demonstrations and providing quality control services. Production and distribution of different biofertilizers were also undertaken but subsequently discontinued as the centers redefined their role towards R&D and HRD related activities. Capacity creation and production was however encouraged through one time grant for new units.

The financial assistance, given as grant-in-aid to the tune of Rs 13 lakh and now increased to Rs 20 lakh per unit and thrown open for all, was routed through the State governments but owing to delays in release of grants the onus is transferred to NABARD/NCDC. The public sector organizations form a bulk of the units in the industry, while similar units in the private sector are also coming forward. Different State governments also provide subsidies sometimes up to 50% of the sales realization but the manner of subsidization is rather unsystematic. In many cases the discrimination and manipulation in subsidizing lead to a lot of intra industry variation in prices. The government also plays a dominant part in marketing biofertilizers in three possible channels: (a) State government via District level Officers and Village level workers to farmers, (b) State Marketing federation via cooperative bodies to farmers and (c) State Agro-industries

Corporations via Agro service Center to farmers. The producers are however free to sell through their own sales network or through market, (i.e., wholesalers and private dealers).

5.4 Data

The Fertilizer Association of India (FAI) periodically presents information compiled on capacity and distribution of biofertilizers by various units. In the absence of reported information on farm level use of the inputs, this can help in understanding the progress of the technology and its adoption in India. The period covered by the data is 1992-93 to 1998-99.

The FAI report gives the distributions of different strains for recent years by states that can proxy for usage by farmers. For a better understanding of the demand for use, firm level information on capacity, distribution and prices would be more useful. However the FAI could not report for all existing producing units due to their non-responses and this irregularity is more for distribution and prices. So the inferences drawn in the present study are only based on the samples that report the required information. The FAI reports (1996, 1998, 2001) give information of annual distribution levels of various inoculants and their sale prices for consecutive years by firms. In addition the annual capacity as of March is provided for the three years 1995, 1997 and 1999.

5.5 Success of Biofertilizer Technology

Government of India and the different State Governments have been promoting use of biofertilizers through grants, extension and subsidies on sales with varying degrees of emphasis. With time farmers too learn about the technology forming their perception on the basis of agronomic realities of their regions, the knowledge gained from experiences of farmers around them and including themselves and the information provided by different disseminating agents and form their own decisions of adoption. Above all the enterprise of the firms working through their marketing, research and development efforts would lead to the widespread use of the inputs once the prospect of profit is sensed. commercial appeal with the passage of time and government support.

Progress of the Industry

Based on the data for 1995, 1997 and 1999 it appears that the industry witnessed a steady increase in the number of units producing the input (Table A4). Over the period of four years the number of units went up by 53% from 62 to 95 and further to 122 in 2002 (Ministry of Agriculture, GOI). The total capacity expanded by 102% going by the information on units reporting their capacities.

New private units joined the industry improving their numeric share while the public sector, after the initial burst slowed its pace. However, a deeper look would be more illuminative.

The total distribution as reported by the unitsⁱⁱ on an annual basis increased over time at an impressive rate of over 50% (Table A4). However it is clear that the bulk of the growth took place by 1992-95 of the sample period and stagnated thereafter. There are also changes in shares by types with moderate success in AZT and by far the best performance by PSB (Table A1). The decline in RHZ indicates success in groundnut and pulses was below expectation. Table 2 gives the distribution and annual capacity of units deflated by the number of units. A measure of capacity utilized is obtained relating actual distribution (as opposed to production) to capacity. The industry has been going through an adjustment of size as average capacity of a unit came down from 261.8 tonnes to 205.6. The capacity addition in the industry was less relative the addition of new units due to entry of lower sized new units. The average distribution also declined in the first two years possibly signaling the need for a down size and picked up subsequently. The average capacity utilization has been poor but the down sizing may have arrested the declining trend.

Diffusion

The chemical based fertilizer technology incorporated in the green revolution was successful by its rapid adoption rate but the unbalanced spread across the country, especially in the eastern region marks a crucial failure. The central government's role in the new biofertilizer technology would be justified by greater spatial dimension of the success.

Table 2 : Average Capacity, Distribution and Capacity utilization of Units			
Year	Capacity (Tonnes)	Distribution (Tonnes)	Capacity Utilisation
1994-95	261.8	111.3	0.43
1996-97	225.8	87.91	0.39
1998-99	205.6	94.37	0.46

Note: Calculated for only Units reporting Capacity, Distribution NBFDC and RBDCs are treated as single unit
Capacity utilization is measured as distribution divided by capacity
Capacity of 1994-95 is as of March 1995 and so on.

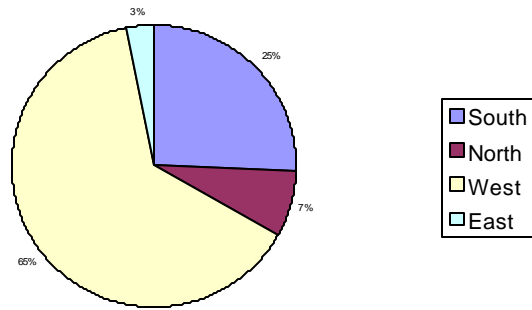
Table 3: Regional distribution of Bio-fertilizer Plants (%)			
	1995	1997	1999
Region			
East	17.74	13.89	12.63

North	29.03	27.78	17.89
West	22.58	26.39	38.95
South	30.65	31.94	30.53
Source:FAI			

Since biofertilizers are perishable and sensitive to quality of handling, the distribution of plants would to some extent reflect the regional distribution pattern. However this is only partially valid as units with large distribution networks do distribute over larger areas. As an example distribution levels of public sector fertilizer giant IFFCO (a late starter) are given in Table A2. Located in Phulpur in Uttar Pradesh, IFFCO's MLN Farmers' Training Institute produces all strains of biofertilizers and have distributed in states other than the home state. Eastern states like Bihar and Orissa are also served though the share has gone down notably for West Bengal where distributions came down to nil in 2000-02. Table 3 shows how the industry started with a fairly even dispersion of units gave way to a concentrated locational pattern. While both east and north lost their shares, there was continuous and significant expansion in the western region. The share of south remained stable. This tendency is further reinforced by the state wise distribution of plants presented in Table A3. Some of the states saw closure of units and in fact over the period the number of units in north actually came down.

The region wise distribution of biofertilizers is more dispersed relative to chemical fertilizers as apparent in Figure 1 with highest share going to west followed by south while north and east claimed lower shares. The distribution does not follow that of chemical fertilizers they supplement, where north is the largest claimant. However the eastern region comes last in share in both chemical and biofertilizers though the share in the latter case is even more diminutive. The comparison however is not complete without bringing in the cropped area in the regions. The use intensities in Table 4 also suggest relatively poor adoption in east and north.

Biofertilizers distributed in Regions



Chemical (NP) Fertilizer distributed in Regions

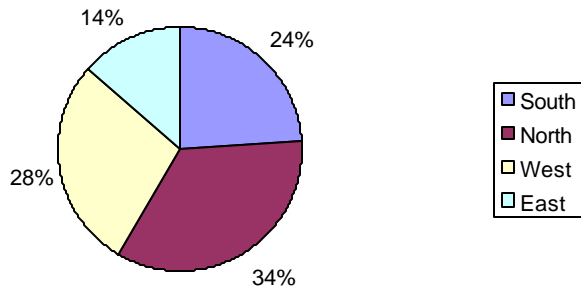


Figure 1

Private enterprise

In the nineties India stepped a market oriented regime and the desired role of the government became one of facilitator. In the past public sector units including state owned cooperative organizations played a crucial role in implementing government's social objectives on a continuing basis, compromising commercial interests in the process. In a more competitive environment failure to attain commercial viability does not augur well for the sustenance of the organizations as also for the public budget. In the case of biofertilizers too the initiative taken by the public sector along with numerous universities and research units that are also state funded must with time lead to commercial success once the technology is transmitted to the field and this

in turn is expected to draw private enterprise since the market is open for entry. The government is also encouraging private entry by extending financial grant to all and

Table 4 : Use intensity of Biofertilizers (BF) and Chemical fertilizers in Indian Agriculture				
Region	Chemical (NPK) (Kg/hect.)	Cropped area (%)	Chemical (NP) (Kg/hect.)	Biofertilizers (Kg/hect.)
South	125.21	18.46	107.06	0.05
North	130.43	22.32	127.65	0.01
West	60.82	40.91	57.07	0.06
East	70.63	18.32	61.73	0.01
Total	90.04	100.00	82.90	0.04

Source: Computed from FAI data. Biofertilizers distribution data reported by units are used.

sundry. Table A4 suggested that slow down in private commercial sector distributions is more pronounced than total.

Although many of the new entries between 1995 and 1999 are private commercial enterprises, their share in total capacity came down steadily as revealed by the reports (Table 5). This is because of scaling down of size from a relatively high level of 504 tonnes to 308 tonnes as already noted. The coexistence of smaller new units with the larger ones of higher vintage has increased the variety in industry as measured by the coefficient of variation. The share in distribution however has been relatively more stable despite showing a slight declining trend in the last five years reported (Table A5). Over the years the industry as a whole distributed about 35.6 thousand tones of which a little less than half is accounted by the commercial private firms. The latter also charged higher prices on the average and there is slight rise in prices between 1995 and 1998.

Table 5: Capacity of Privately owned Units			
	1995	1997	1999
Average Capacity (tonnes)	504	437	308
Coefficient variation (%)	120	143	162
Share in total capacity (%)	74	69	67

Note: Calculated for Units that reported Capacity

Structure of Industry and Econometric Analysis to explain Distribution

Based on the 50 units that reported capacity (details given in Appendix A-II), distribution and prices in 1998-99, accounting for nearly 85% of distribution Table A5 presents the structure of the industry. An econometric analysis will attempt to use this information to explain the distribution performance by the structural components of the industry. The capacity of a unit is defined by the various facilities of production including equipment for various operations, infrastructure and space. Labour and raw materials are essential variable inputs for actual production as summarized in Appendix A-I for a given capacity and using this general norm and the actual production levels, annual man-days of employment generated by a unit can be estimated. Due to the complex nature of the process involving laboratory culture of life forms, that requires definite combinations of space, equipment and time, there is little substitutability among the inputs.

Numerous studies on technological evolution emphasized the developmental role of a firm (Chandler, 1993) and the strength of its sales network, creating market and drawing market feedback, for its success. In general, firms with larger production facilities are expected to invest more on networks to understand and access the market but it is not uncommon for firms with larger distribution networks to act as marketing agents for smaller units who are lacking and in few rare cases like that of NAFED the distribution even exceeds capacityⁱⁱⁱ. The sales networking would be stronger also for concerns that are in some way already in the business of selling agricultural inputs. Since the exact scope and nature of the units or possibly their parent companies is not clear from the data, past experience in selling biofertilizers may be considered as an indicator of their marketing capabilities. Judging by the sample information, units that record a cumulative distribution of more than 100 tonnes over the previous 3 years are deemed to be enjoying greater selling experience and broad based net-workings. While the cumulative distribution performance takes care of 'learning by doing' opportunity of the firm a possible additional characteristic could be the age or vintage of the unit, which also allows for 'learning by looking' opportunity. Since data on vintage is not readily available, those that existed and reported for March 1995 are classified as older units (VINT). Units that produce both nitrogen fixers and phosphate solubilisers are categorized as joint producers (JOINT).

Production of biofertilizer started in India with significant government involvement with active participation of the public sector that is directed more by public policy and social objectives than

profit. The extent of commercial success would be indicated by the participation of private commercial units so long as market is free for entry. The private firms that reported can be categorized as private (PVT) and others that include universities, research institutes, cooperative, agro-marketing and other public sector organizations. Finally, the regional distribution of the firms is of interest in view of the tendency of concentration observed.

Going by a size categorization of units based on sample average capacity of the units as the cut off size, less than 30% of units are classed as large, with majority being relatively small units. The share of private sector is much larger (64%) for the smaller units than the larger ones (36%). More than 70% of the large units are of longer vintage reiterating that new entry has been mostly in small units. About 70% of the small units came into being after March 1995. The small units show some tendency to specialize in either nitrogen fixers or phosphate solubilisers while all the large units produce both kinds. Both size categories show regional bias for west, followed by south, though smaller units have relatively greater presence in south as also in east where there is no presence of large units. The average capacity differs widely between the two categories, as does employment generation but large units record higher capacity utilization. Average price charged is marginally in large units.

The following equation is estimated to explain distribution:

$$D_j = \hat{a}_0 + \hat{a}_1 P_j + \hat{a}_2 \text{CAPACITY}_j + \sum_k \hat{a}_{3k} \hat{a}_k$$

Where D is distribution in tonnes in the completed year, P is sale price in Rupees per kilogram, CAPA is capacity in tonnes at the year end and \hat{a} are k dummy variables corresponding to unit j. Price, calculated as weighted average price of different biofertilizers (PBIO) with distribution shares as weights, varies moderately among the units. As a deflator the price (PCHEM)² of chemical fertilizers, N and P, are taken for the year and weighted by consumption shares in the state concerned. The deflated price variable P-DEF is expected to show a negative effect so long as there is some competition between chemical and biofertilizers. A specification including both prices separately is also estimated. CAPACITY of the unit accounts for scale of the unit and the

² The weighted average price of biofertilizer is over the different material products while that of chemical fertilizer is over nutrient contents. The two averages are not entirely comparable, but at this early stage of the technology, the absence of information of available and stable conversion rate of biofertilizer into nutrients offers no better specification opportunity. The deflated price variable PDF may be taken as a multiple of the true relative price, which can be estimated only when the true conversion rate is known. Nitrogen equivalences given in Table 1 are not used, as their meaningfulness is still debatable.

dummy variables place the units in different categories that could have a bearing on distribution. Variable DUM-EXP is used to capture units with selling network as indicated by past experience as discussed. Another variable for experience is VINT. Dummies WEST, EAST and SOUTH delineate the units by three major regions to see if any one region makes a difference over all others including north. Variable PVT is used to examine the performance of units in private commercial sector. Similarly, variable JOINT helps find out if varied production pattern is an added advantage. Heteroscedasticity consistent estimates of parameters are provided in Table 6.

Dependent variable is DISTRIBUTION					
	Specification 1			Specification 2	
Variables	coefficient	t-statistics	Variables	coefficient	t-statistics
CONSTANT	34.648	0.539	CONSTANT	-463.44	-0.642
P-DEF	-2.919	-0.145	PBIO	-0.123	-0.074
CAPACITY	0.328	9.409	PCHEM	49.369	0.648
DUM-EXP	73.349	2.495	CAPACITY	0.326	9.406
DUM-PVT	-46.714	-2.203	DUM-EXP	76.609	2.387
			DUM-PVT	-50.572	-2.048
R		0.75			0.76
DW		1.6			1.50

The equations coming with reasonably good fit show expected signs of price and scale variables though there is no significant effect of price. The scale variable CAPACITY has a positive and significant coefficient. Firms with greater selling experience (DUM-EXP) also distribute significantly higher amounts given other conditions unchanged. Variable PVT comes with a negative coefficient suggesting that private commercial units distribute less than others after controlling for price capacity and experience. The estimates presented in Table A6 also suggest this implication even with varied specifications and with an altered sample where the largest and smallest distributing units are excluded. The region dummies too peculiarly indicate the near absence of regional dimension in the distribution after controlling for relevant factors. Even units located in the western region, which claimed the maximum expansion of the industry, shows no remarkable advantage over others and the variable comes with an insignificant and even a negative coefficient. Joint production of different biofertilizers gives no added advantage over specialized units and older units shown by variable VINT do distribute more, possibly gaining from being in the field for long.

Empirical findings: Summary

The analysis conducted with the limited data available throw some light on the progress of the technology through the indirect indicators from industry. The empirical findings can be summarized as follows:

First, the distribution of biofertilizers, proxying for its adoption rate has not consistently grown over time and has slowed down in the late nineties. Starting from a small base one would have expected a faster and possibly accelerating growth performance as the input finds greater acceptance. Second, although there have been more and more new entries in the market, the average capacity came down characterizing the industry by a large number of small units. While size adjustment in infant industry is normal, it must be borne in mind that distribution of an agro input also calls for substantial sales networking and a deep understanding of the field reality in agriculture. Whether the smaller units will have the necessary expertise and incentive for meeting farm demands or synergical associations with bigger producers or simply distribution agents or local bodies would be the desired institution is matter of review. Third, there has practically been no diffusion of the technology despite the central government's interventions and the distribution among units has tended towards greater concentration especially in Maharashtra and other states of the west and south. As with chemicals, the impact on the east has been poor. Possibly the interventions and the policy of the State governments proved more decisive and in some cases, the recommendations of the agricultural universities or lack of them (as in Punjab) had a role in the farmers' lack of interest in the technology. Fourth, despite entry of private players, the share of the private commercial sector in distribution remains below 50% and over time the private firms have neither improved their share in capacity or distribution nor their growth rate of distribution. This casts doubt on whether the business is as of now viewed as a commercially gainful prospect. Fifth the regression analysis further brings out some aspects of concern. There seems to be little intrinsic justification for the regional preferences shown by units since the distribution performance does not appear better in any region, even the west, than others after controlling for unit size and price. Further, given the capacity of the unit, private ownership has an adverse effect on distribution performance and this once again raises questions on commercial viability of the industry.

5.6 Why the government needs to intervene

The result of the analysis is not positive with respect to government intervention in the market is concerned. Till date the central government has spent several crores of rupees as grants to invite

investment and state governments have also spent large sums for subsidizing and promoting use. The questions that now arise are (a) Does the government need to intervene and support the market to build up? (b) If so what should be nature of intervention?

Despite the lack of expected response there still is a strong case for government to intervene and possibly subsidize in the market. The reasons can be broadly classified in two groups:

Social gains or 'First best' reasons

If biofertilizers impart certain social and long-term gains for which private individuals may not be willing to pay at least until the gains become 'visible', there is a rationale for spreading the cost over a larger group of beneficiaries or the society at large (Yokell, 1979). The government can act on behalf of the society through appropriate policy even if the market is otherwise competitive.

1. Biofertilizers have important environmental and long-term implications, negating the adverse effects of chemicals. At the farm level, the gains from increased use of the technology can spill over to other farms and sectors through lesser water pollution than chemical fertilizers and even to an extent organic manures can create.
2. The gains from the new technology coming through the arrest of soil damage may not be perceived over a short span of time unlike for chemical fertilizers, which yield quick returns. At the same time the farmer has to incur considerable initial cost in terms of skill acquisition, trial and failure and risk. In agrarian situations where agents often operate with bounded rationality, adoption may be slow and influenced greatly by neighbours' experiences over time. Empirical evidences in agriculture around the world show that adoption of new practices take time to pick up and the earliest adopters are often conservative about the percent of acreage (Griliches, 1957) devoted to the new technology. The state has a role to play in inducing farmers to adopt improved practices.
3. The producer firms have serious uncertainty about the demand or saleability of the product, which deters investment, particularly if it is irreversible (Guiso and Parigi, 1999). The success or failures of early entrants who take the initiative or those who indulge in research for an improved product convey important information to others (Stiglitz, 1989) and thereby to society. The market however does not always reward the initiative. The capital market is also not always ready to provide the risk capital at reasonable rates.

Non-competitive Market or 'Second best' Reasons

In many cases the market itself is not competitive and although the first best solution would be to promote competition, there are other ways of dealing with the situation.

1. Although biofertilizers have been promoted as supplement or complement of chemical fertilizers, in reality they are two alternative means of accessing plant nutrients. The strength of complementarity as against substitution between the two inputs is open to empirical verification, but there is no denying that farmers and producers do perceive the substitutability relation to an extent. The pricing of chemical fertilizers is far from marginal cost based. In particular urea is under administrative pricing and there are serious economic and political compulsions to continue the protection although the movement in spirit has been towards openness. In such circumstance the price of biofertilizers along with the risk and responses will be weighed with those of chemical fertilizers, and promotion of the technology for environmental reasons would call for some degree of protection to minimize the inter-fertilizer price distortion.
2. The external or environmental cost of using chemical fertilizers, though not measurable may also be taken into account when comparing with biofertilizers if the latter is to be promoted.

The next question that arises is what should be the nature of intervention. With the results at hand, the central government needs to improve its strategy towards a more broad-based and integrative role in order to provide the correct environment for the adoption of the technology.

One of the main barriers faced by the producers and investors is inadequate demand and the inconsistent and seasonal nature of the existing demand. It may be recalled that the technology is as yet nascent and evolving. The rice dominated eastern region remains a non-starter and the wheat-rice growing north has not shown much interest either. Research on developing efficient, temperature tolerant and hardy strains is a vital step to the actual success of the technology. In particular, there can be some focus on the potentials of the technology in rice and cereals in general although its significance for crop diversification is of equal concern. Similarly development of suitable carriers, better packaging and longer shelf life are also important for commercial acceptance of these living inputs. The government has a dominant role to play in encouraging and funding research either by universities or private firms to make up for shortfall in private commercial research initiative. As is well recognized now, in a market-oriented system,

information is often scarce and costly and hinders many business activities. For biofertilizers, the government has a dominant role of disseminating the technology through demonstration, training and other activities. A proposal to make it mandatory for biofertilizer units to contribute in the process through their own demonstration is a welcome step. Research and extension/promotion both must be to the extent possible specific to local conditions and constraints.

It is a good practice to promote biofertilizers as an input conjunctive to other forms of fertilizers, but keeping in view the protection given to chemicals, there is some ground for subsidizing the former to encourage their use. However, there is a need to work out a systematic and uniform way to give out subsidies so that they do not distort inter unit prices and help some units at the cost of others. The States should be strongly guided on this norm. The main purpose of the subsidies would however be to induce farmers to try out the input at affordable and acceptable prices rather than to support certain producers directly. As far as producers are concerned, a healthy competition would only help develop a market in the long run and benefit the farmers. Open sales in the market may be encouraged to improve the capability of the units in marketing products. Any attempt to fix a minimum price for the sake of quality or other consideration will only go against the spirit of competition and harm the interests of the industry and the farmers. The present study finds some but not conclusive role of the price factor but scientific studies may be conducted on the farmers' 'willingness to pay' for the new input to determine the need and extent of subsidies.

The subsidy, if it is considered desirable, could be routed through the Ministry of Environment since the main aim of the policy is to encourage environmentally improved practices.

Quality is an essential element in this market and the entry of new units also heightens the threat of poor strains appearing in the market and ruining the farmers' confidence in the technology and their incentive to adopt the same. There is a strong case of quality control and legal safety nets, which could possibly draw the involvement of local bodies backed by the expertise of specialized agencies. Since the microorganisms are extremely perishable and sensitive to local conditions and handling the farmer always encounters some risk in opting for the input. To the extent the farmers' risk perception is responsible for inadequate adoption there is a case for spreading the risk over a larger society. An insurance or a buy back scheme could work with the cost shared by the government and the producers but this would call for some monitoring of farmers' behaviour. Such a scheme would also reduce the need for subsidies.

The grant in aid given for new units and possibly in future for upgrading older units is not really a desirable method. To the extent that inadequate demand is the main hindrance to producers, the financial aid would not help at all. In fact the method embodies an incentive for *moral hazard* where the firm receives the grant but does not make enough 'effort' to sell. The transfer of the responsibility to NABARD would only impose undue burden on the bank in monitoring sales attempts. The regression analysis says that even with the same capacity build up (with the help of grant), a private commercial unit sells less than others. In actuality, business organizations have their own dynamism and sales effort would definitely follow from commercial prospects, which can come from greater acceptability on the users' front. Concessional finance could be arranged for investment to encourage investment as well as efficiency in follow up business.

The scaling down of average size of unit must be associated with a review of sales and development capability of units. It is noted that smaller units do not necessarily enjoy higher capacity utilisation in terms of distribution. The broader networks, deeper understanding of market and greater sales experience of older and larger units, specifically the cooperative sector units involved in marketing other agro inputs may be commercially exploited for the marketing of products produced by smaller and less experienced units and the development of a synergic system in this regard may be useful.

Policy Options: Summary

There are two layers of challenges with regard to incentive and risk that the government has to encounter in the process of launching the biofertilizer based technology in agriculture, one at the level of farmers or users and the other at the level of the producing units or investors. This paper suggests that the government emphasizes the former since the field level acceptance of the technology will gradually bring commercial viability of producers. For greater farm level acceptance the government can do the following:

Research: Promote and fund research for improved strains suitable for the different conditions, especially for the east and for crops like rice. Greater crop diversification will also stimulate diffusion.

Risk insurance: Explore the possibility of insurance or buy-back of products to reduce farmers' risk, with the cost of the scheme being shared by the government and the distributing/producing firm.

Subsidies: (i) Assess the need for subsidizing sales through scientific studies on 'willingness to pay' and provide for affordable inputs to encourage acceptance at this stage. Discriminatory and non-uniform subsidies must be removed at once for effective and undistorted incentive to firms.

(ii) Involve the Ministry of Environment in subsidization and the local bodies for effective monitoring and regulation.

Information: Organise promotional campaigns and demonstrations drawing the cooperation of producers and gather market feedback for effective utilization in further research and in improving the operations and management of producers.

On the producers side the recommendations are few as the above measures, if effectively implemented could go a long way in benefiting the producers too. The study however suggests:

Research grants: Funding of possible research for improvement of strains.

Sales networking: Work out suitable sales and development networks among distributors and producers.

Market support: Provide some market protection through government purchases for specific time period subject to stringent quality control. This is to be phased out and open market sales encouraged.

Finance: Concessional finance for investment may be made available. Financial outright grants are not advisable.

5.7 Conclusion

Critics have argued that Green Revolution simply borrowed production from future generations as it impoverished soils and destroyed ecological balances. Environmentalists have further pointed out that the emerging free trade regime would raise the scale of activity, especially with respect to products with comparative advantage, leading to greater environmental damage. While all this may be an extreme view and a debatable one, the need for undoing to the extent possible of ecological problems of the past and introducing more sustainable patterns in future cannot be overemphasised.

The Government of India has been promoting the use of biofertilizers in agriculture through the NPDB and the state governments also added to the process via subsidization and extension. Based on living micro-organisms these inputs can make nutrients abundantly available in atmosphere and soil accessible for plant use without the adverse impact that chemical fertilizers have on soil, water and air. The national scheme sought to spread the new biofertilizer based technology through field demonstration, research and financial assistance to investors.

Based on the data provided by the Fertilizer Association of India this study finds that despite efforts the use of the input as indicated by the distribution has not grown steadily over time, has been way below projected levels and there has been practically no diffusion across states, with about 90% of use accounted by western and southern regions. There has been entry of new units and significant capacity built up but average capacity has come down with a marginal improvement in capacity utilization. Private commercial units though open to entry have not improved their share in distribution. A regression analysis suggests that given the same capacity and other relevant conditions a private unit distributes less than others casting doubt on the commercial success of the industry. The analysis also indicates there is no intrinsic advantage that accounts for the evident concentration of the industry in specific regions. The State governments' own initiative possibly had greater role in guiding the spread of the technology than the central government's schemes.

Public intervention through monetary or other means is justified for building up a market for an input promising social and longer term gains. The emphasis of any government policy would be in popularizing the use at the farmer level through varietal improvement, information dissemination, risk coverage and also sales subsidies if justified by scientifically conducted studies. The acceptance at the farmers' end would go a long way in providing commercial

benefits to producing units and encouraging investment. The government must however help the units financially or otherwise in developing suitable strains and carriers, in accessing affordable finance for investment and in working out viable schemes for distribution especially since smaller and less experienced units are tending to dominate the market.

Appendix

Tables

Year	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Total (tonnes)	1600.01	2914.37	4988.90	6288.32	6681.44	6295.63	6700.27
% share							
Rhizobium	57.27	40.50	29.41	21.15	20.84	19.85	18.62
Azotobacter	13.00	22.20	18.47	18.46	15.51	17.30	17.74
Azospirillum	12.54	11.11	14.08	17.99	11.34	10.17	11.77
Nitrogen fixers	82.81	73.80	61.96	57.61	47.69	47.32	48.12
Blue green algae –	0.00	0.00	0.06	0.04	0.01	0.02	0.04
phosphate solubiliser	17.19	26.20	35.77	40.46	49.88	48.75	48.98
acetobacter	0.00	0.00	2.21	1.90	1.13	1.06	1.00

States	Years	%Total
Uttar Pradesh	1996-97	93.29
	2001-02	47.97
Uttaracnchal	2001-2002	6.12
Punjab	1996-97	0.00
	2001-2002	10.64
Haryana	1996-97	0.00
	2001-2002	5.53
Rajasthan	1996-97	0.00
	2001-2002	5.53
Maharashtra	1996-97	0.00
	2001-2002	2.63
Madhya Pradesh	1996-97	0.00
	2001-2002	0.01
Bihar	1996-97	0.00
	2001-2002	7.01
West Bengal	1996-97	6.71
	2001-2002	0.00
Orissa	1996-97	0.00
	2001-2002	0.00
Source: IFFCO		

State	Number	Number	Number	Net Addition	
	31.3.95	31.3.97	31.3.99	1995-97	1997-99
Assam	2	1	2	-1	1
Bihar	2	2	3	0	1
Orissa	2	2	1	0	-1
West Bengal	4	3	5	-1	2
Manipur	1	1	1	0	0
Tripura	0	1	0	1	-1
East	11	10	12	-1	2
Haryana	2	2	2	0	0
Himachal Pradesh	1	1	1	0	0
Punjab	1	1	1	0	0
Uttar pradesh	13	15	12	2	-3
Delhi	1	1	1	0	0
North	18	20	17	2	-3
Andhra pradesh	4	3	3	-1	0
Karnataka	6	5	11	-1	6
Kerala	0	1	1	1	0
Tamil Nadu	9	13	13	4	0
Pondicherry	0	1	1	1	0
South	19	23	29	4	6
Gujarat	3	3	3	0	0
Madhya Pradesh	4	4	7	0	3
Maharashtra	5	8	24	3	16
Rajasthan	2	4	3	2	-1
West	14	19	37	5	18
India	62	72	95	10	23

Category	Total units number	Private Units %	Old units %	Producing both NF and PS %	Regional distribution of units %				Average Capacity Tonnes	Average Distributio/ Capapcity%	Average Price Rs/Kg	Employment Mandays/ year
					West	South	North	East				
Large	14	36	71	100	50	36	14	0	613	50	29	4360
Others	36	64	31	86	50	36	3	11	100	36	30	447

Note: Only units reporting capacity, distribution and prices in 1998-99. NBFDC considered in North region.
Price is simple average of firms.
Large unit is defined as having capacity above sample average (243.53 tonnes).
Older units are units that reported for 1995 March

year	Distribution(Tonnes)			Price of NF (Rs/Kg)			Price of PS (Rs/Kg)		
	Total	Private	Private(%)	Total	Private	Total%	Total	Private	Total%
1992	1599.90	738.70	46.17	27.47	31.12	113.29	30.55	39.20	128.31
1993	2914.30	1763.80	60.52	29.27	33.50	114.45	31.30	39.70	126.84
1994	5008.60	2449.90	48.91	27.10	30.89	113.99	27.39	30.61	111.76
1995	6363.28	3341.35	52.51	27.80	31.52	113.38	28.28	32.16	113.72
1996	6681.50	2823.22	42.25	23.79	28.87	121.35	25.39	30.46	119.97
1997	6295.60	2714.22	43.11	24.99	29.78	119.17	26.93	32.55	120.87
1998	6699.90	2769.92	41.34	27.90	32.13	115.16	29.38	32.27	109.84
1992-98	35563.08	16601.11	46.68	26.90	31.12	115.66	28.46	33.85	118.94
Annual average Growth rate%									
1992-95	99.24	117.44	4.58	0.40	0.43	0.03	-2.48	-5.99	-3.79
1995-98	1.76	-5.70	-7.09	0.12	0.65	0.52	1.30	0.11	-1.14
1992-98	53.13	45.83	-1.74	0.26	0.54	0.28	-0.64	-2.95	-2.40

Note: Units that report capacity and distribution only considered. Prices are simple averages across units. For period 1992-98 total distributions and simple average prices are reported. Growth rate is based on point to point comparison.

Dependent variable is DISTRIBUTION											
Variables	Specified with VAR=VINT		Specified with VAR=JOINT		Specified with Regions						Es sa
	coefficient	t-statistics	coefficient	t-statistics	VAR =WEST		VAR=EAST		VAR=SOUTH		
CONSTANT	26.113	0.413	28.948	0.494	36.82	0.634	34.681	0.535	32.371	0.416	
P-DEF	-2.079	-0.104	-3.276	-0.158	-2.696	-0.126	-2.675	-0.127	-2.337	-0.099	
CAPACITY	0.325	9.209	0.328	90.334	0.330	9.499	0.328	9.281	0.330	9.482	
DUM-EXP	60.674	2.088	71.986	2.473	72.504	2.289	72.597	2.348	71.894	2.058	
DUM-PVT	-44.111	-2.149	-46.780	-2.174	-47.607	-2.300	-46.678	-2.173	-48.241	-2.391	
VAR	26.315	1.066	8.272	0.504	-4.738	-0.175	-5.275	-0.202	4.610	0.140	
R		0.75		0.75		0.75		0.75		0.75	
DW		1.53		1.5		1.5		1.5		1.6	

Appendix A-I

Requirement of Some Inputs for Production of Biofertilizers

Production capacity 75 tonnes/year equivalent to 375000 packets (each packet 200 grams)

Labour use

Number of working days 240 days

Number of shifts 1 = 8hours

Number of daily wage labour

Unskilled 3

Skilled 1

Total man hours per year

7680

Carrier for 1000 packets 120Kg (Peat, Lignite, Charcoal)

Equipment (Autoclave, Refrigerator, Hot air oven, microscope etc.)

Packaging material (LDPE, HDPE, Polypropylene).

Rooms for Inoculum, Carrier, Office.

Source: BioFertilizer Statistics 1999-2000

Appendix A-II

Units considered for Regression Analysis accounting for 85% of Distribution 1998-99

Names of Units

<0.2% total distribution

Micro Biological laboratory ,Pattambi

Pyrites, Phosphates and Chemicals, Amjhore

College of Agriculture, Marathwada Agricultural University, Parbhani

University of Agricultural Sciences, Dharwar

Bharat Laboratory & Biological House for Agriculture, Dhule

Godavari Fertilizers & Chemicals Ltd., Secundrabad

Lakshmi Bio-techs, Cuddalore

Regional Soil Testing Laboratory. Rajendranagar

Ecosense Labs (I) Pvt. Ltd., Goregaon

Nodule Research Laboratory, BCKV , Mohanpur

Bio Science Laboratories, Salem

Micro Bac India, Shyamnagar

A.V.S. Agro Products, Ahmednagar

Institute of National Organic Agriculture (INORA), Pune

Nav Maharashtra Chakan oil Mills Ltd., Pune

0.2% to 1% of total distribution

Biological Nitrogen fixation Scheme, College of Agriculture, Pune

Kisan Agro Chem, Dhanegaon

Magnum Associates, Chennai

Monarch Biofertilizers and Research Centre, Chennai

Samarth Bio Tech Ltd., Hubli

K-Ferts Lab, Nanded

Samruddhi Agrotech, Pune

Rhizobium Scheme Deptt. Of Agriculture, Durgapura

Maharashtra Bio-tech Industries, Pune

Maharashtra Bio-tech Industries, Pune

Vasantdada Sugar Institute, Pune

State

Kerala

Bihar

Maharashtra

Karnataka

Maharashtra

Andhra Pradesh

Tamil Nadu

Andhra Pradesh

Maharashtra

West Bengal

Tamil Nadu

West Bengal

Maharashtra

Maharashtra

Maharashtra

Maharashtra

Maharashtra

Tamil Nadu

Tamil Nadu

Karnataka

Maharashtra

Maharashtra

Rajasthan

Maharashtra

Maharashtra

Maharashtra

Nitrofix Laboratories, Calcutta	West Bengal
The Sima Cotton Dev. & Research Association, Coimbatore	Tamil Nadu
M.A.I.D.C. , Pune	Maharashtra
Niku Bio-research Lab, Pune	Maharashtra
1% to 5% of total distribution	
T.N.Agricultural University, Coimbatore	Tamil Nadu
Tejasvi Biofert, Pune	Maharashtra
Gujarat State Cooperative Marketing Federation Ltd., Kankaria	Gujarat
HMG Biotech Pvt. Ltd., Shimoga	Karnataka
MLN Farmers Training Institute (IFFCO), Phulpur	Uttar Pradesh
SPIC Bioproducts, Chennai	Tamil Nadu
Main Bio Control Research laboratory (TN Cooperative Sugar Fedn.) Changalpattu	Tamil Nadu
Deptt. of Agriculture, various	Uttar Pradesh
M.P.State Cooperative Oil seed Growers' Federation, Dhar	Madhya Pradesh
Rashtrya Chemicals & fertilizers Ltd., Mumbai	Maharashtra
Bio Agro Fertilizers, Pune	Maharashtra
terra Firma Biotechnologies Ltd., Hubli	Karnataka
Kribhco, Hazira	Gujarat
Bio-fertilizer Production unit, Deptt. Of Agriculture, Pudukottai	Tamil Nadu
G.S.F.C., Vadodora	Gujarat
Bio-fertilizer Production unit, Deptt. Of Agriculture, Salem	Tamil Nadu
National Biofertilizer Development Centre, Ghaziabad etc.	Uttar Pradesh etc.
Madras Fertilizers, Manali	Tamil Nadu
>5% of total distribution	
Nafed Bifertilizer, Indore	Madhya Pradesh
Ajay Bio-tech India, Pune	Maharashtra
Kumar Krashi Mitra Bio Products (I) , Pune	Maharashtra

ⁱ BGA's role in maintaining natural fertility of water logged rice fields by scientists back in 1939, when there was no use of chemical fertilizers to speak of.

ⁱⁱ Since all units have not reported their performance these distributions relate only to those that reported them, chances being that non-reporters are non-significant distributors.

ⁱⁱⁱ The scope of selling from carried over stocks is limited as shelf life is short, around six months.