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Research Article

# The Lacuna between R&D and Technological Commercialization of Biofertilizers in South Asian Countries

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## INFO

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## ABSTRACT

The study is aimed at explaining the necessity to think of worthy alternatives in the field of agricultural promoters and moreover, the application of the same with proper initiatives and infrastructure. It describes the availability of biofertilizers in South Asian countries, which has an agro-based industry, which employs at least 10% of the total population of the country besides which, it also describes some established and ongoing research proceedings in these particular few countries in the field of biofertilizers. Chemical fertilizer industry has grown largely in these areas due to the overwhelming population in this region and to provide food security to the same, the most easily available productive, fertilizers in the market are the ones with a chemical composition. Though, in larger economies like India and China the setup is in terms of number of manufacturing units but proper marketing of the product still needs a boost. Although government of all the countries have taken significant steps towards making agriculture of the respective countries cleaner and greener by taking up significantly important policies pertinent to biofertilizers and thereby deviating from the regular use of chemical fertilizers. It has been found in many established researches around the globe that the use of chemical fertilizer has long term side effects, affecting both the user who is a producer of agro-products as well as the consumer who is a buyer of the same. In the 21$^{st}$ century, where horizons know no boundaries, it is time for developing nations to take the leap forward in terms of food security and provide every possible support to the organizations that is actively involved in research, in on field applications and the manufacturing biofertilizers. The benefit to cost ratio for biofertilizers is a sustainable one and by application of these products we would be doing good to the environment and would be placing a foundation stone for a secure future. The study done here is an honest effort towards developing a well recited notion of promotion, commercialization and usage of biofertilizers in South Asian region where countries generate about 10-45% of their revenue and bulk portion of their GDP (gross domestic product) through agriculture. The effort is to bring in righteous information of the above mentioned areas into one common platform for all the countries taken into consideration. It would thereby, bring in new dynamics to the field of biofertilizers and would also bring an opportunity to review the current scenario, thereby replacing whatever mordant approach was taken in this particular matter by the people related with this field. Besides new avenues for development of the same can be thought of and the lacuna between R&D and technological commercialization would be reduced to a minimum.

**Keywords:** Biofertilizer, GDP (Gross Domestic Product), Per Capita Expenditure, Commercialization, Market Value

## Introduction

The application of biotechnology in South Asian countries has certainly opened a wide spectrum of applicative engineering in the field of biofretilizers. Countries like India, Iran, Bangladesh, Pakistan, Sri Lanka and to some extent China depend on agriculture for development of their economy. Table 1 will enlighten us on the GDP (gross domestic product) and per capita expenditure of the following countries.

**Table 1.The nominal GDP of the countries as of 2011-13 and nominal per capita expenditure as of 2011-13[1]**

| Country | GDP ($) [nominal] 2011-2013 | Per Capita Expenditure($) [nominal], 2011-2013 |
|---|---|---|
| India | 1.947 Trillion | 1592 |
| Iran | 548.590 Billion | 7207 |
| Bangladesh | 153.72 B illion | 1044 |
| Pakistan | 230.525 Billion | 1410 |
| Sri Lanka | 64.914 Billion | 3130 |
| China | 9.182 Trillion | 6747 |

The countries mentioned are riverine countries with rich fertile plains suitable and sustainable for agriculture. The population in all of these countries is growing day by day. One- third of world's total population resides in these parts. The increasing demand of food with respect to the increasing population needs proper improvisation which will lead to a 'production surplus' and thereby would create a sustainable environment, where with growing land crisis, the agricultural production would not be hampered. Biotechnology along with biofertilizers comes to the scenario as a potential worthy alternative to chemical fertilizers which is already there in the market. The reason behind using biofertilizers would be that it is a long term alternative and is environment friendly with no potential harmful effects reported till date. First world countries in the west have already started to build proper infrastructure in terms of creating a biotechnology industry which will in long term become a potential tool in combating environmental challenges in the 21$^{st}$ century.

Biofertilizers are defined as preparational mixtures containing living cells or latent cells of efficient strains of microorganisms that help crop plants' for uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of certain nutrients in a form that is easily assimilated by plants. Bio-fertilizers multiply nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth promoting substances. Biofertilizers can be expected to reduce the use of chemical fertilizers and pesticides. Bio-fertilizers are eco- friendly organic agro-input and more cost effective than chemical fertilizers. Bio-fertilizers like Rhizobium, Azotobacter, Azospirillum and Blue Green Algae (BGA) are in use since a long time ago. Very often, microorganisms are not as efficient in their natural surroundings as one would expect them to be and therefore artificially multiplied cultures of efficiently selected microorganisms play a vital role in accelerating the microbial processes in soil. Therefore, application of biofertilizers is recommended on a mass scale so as to reduce the potential threat of sustainable survivability.

## Advantages

- Prolonged microbial function improves soil fertility. It maintains the natural habitat of the soil.
- It increases crop yield by 20-30%, replaces chemical nitrogen and phosphorus by 25%, and stimulates plant growth. Hence it is supplementary to chemical fertilizers.
- It can also provide protection against drought and some soil-borne diseases.
- Biofertilizers are cost effective relative to chemical fertilizers. They have lower manufacturing costs especially regarding nitrogen and phosphorus use.
- It is environmentally friendly since it not only prevents damaging the natural source but also helps to some extent to cleanse the plant from precipitated chemical fertilizer.

- Organic fertilizers have been known to improve biodiversity (soil life) and long- term productivity of soil, and may prove a large depository for excess carbon dioxide.
- Organic nutrients increase the abundance of soil organisms such as fungal mycorrhiza, which aid plants in absorbing nutrients & help in secreting certain growth promoting substances.
- They improve soil structure (porosity) and water holding capacity & enhance seed germination.
- They increase soil fertility and fertilizer use efficiency and ultimately the yield of crops.

## Analytical Approach to the Current Scenario India

The current scenario states that while 14% of the Indian economy depends upon agriculture. 57% of the total employment sector revolves around agriculture in this country. The green revolution brought impressive gains in food production but with insufficient concern for sustenance of soil and agriculture. In India, fossil fuel based chemical fertilizer is the area of interest for commercial fertilizer producer as it produces high dividends with low inputs and is also a hit with small scale farmers because of cheap price and easy availability. Entire dependence on chemical fertilizers in crop production also threatens for disproportionate supplement of nutrients to crops and deterioration of soil health. Proportionate application of green inputs viz., biofertilizers and biopesticides is the spontaneous answer to alleviate problem. However, it is difficult to estimate the total size of green inputs market in India because of its diversity in terms of products and also due to the nature of it being an unorganized market and at the same time lack of infrastructure to support the basic principle of 'technology push-market pull' fails to comply with the crisis. The urge to commercialize biofertilizers on a mass scale would only be possible in this country on the basis of different factors affecting the aforesaid. The commercialization of biofertilizers started in India in the year 1934 with the production and marketing of about less than a ton in a year. India has now emerged as the largest biofertilizer producing country in the world. The current annual production of biofertilizers in India is only 13,000 metric tons against the actual potential demand of 3.4 lakhs metric tons a year. The production of such biofertilizer undertaken mainly by the agricultural research system in India is able to meet only 4 per cent of the potential demand. This indicates the potential for substantial growth in this microbial industry. Therefore, public sector fertilizer units and private entrepreneurs have to enter this field in a big way to fill this gap. The Government of India is encouraging biofertilizer industry by providing subsidies. The system of quality control mechanism and certification has to be put into place at the earliest. Scientists and extension workers need to evolve protocols for the use of biofertilizers and demonstrate their efficacy to the farmers so that their use is increased.[2]

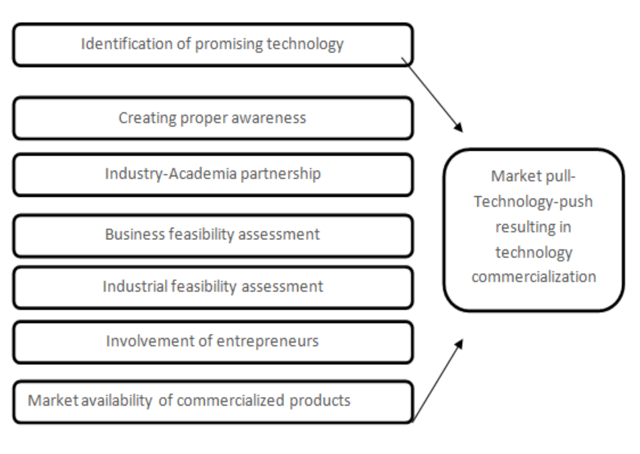


**Figure 1.Flowchart shows the necessity factors to augment biofertilizer commercialization**

## Population: Demand: Supply Ratio

It continues to grow at fairly high rate, posing a serious threat to the National food security. It has been estimated that by 2025, the population will reach 1.3 billion with the potential demand of 315 million tons of food grains. At the end of the year 2010, an increase of at least 25-30% in rice production has been targeted by the government to make the country self-sufficient. The current average production of rice in India at 1.9 t/ha is very low compared to many other countries in the world and there is ample scope for improvement in a drastic way with modern rice production management including Fertilizer Use Efficiency (FUE) and Integrated Nutrient Management (INM) to reach an average yield level of 4 to 4.5 t/ha. Nitrogen is the key for realizing the potential yield for modern high yielding rice varieties and about 20 kg N is removed from the soil to produce one ton of brown rice. The total Nitrogen requirement for a modest yield level of 5 t/ha works out to be 100 kg/ha, of which soil could supply 50-80 kg and the remaining 20-50 kg has to be added externally. Considering that the efficiency of applied fertilizer N is below 40-50%, at least 40-100 kg of fertilizer N/ha will be required to achieve this target yield. However, a majority of rice farmers in India, having marginal and small holding in terms of monetary consolidation, are poor and can hardly afford the use of adequate amount of costly chemical fertilizers. Thus, it is necessary to look for an alternate source of Nitrogen to meet the rice crop demand. Besides, the continuous and exclusive use of chemical N fertilizer not only endangers the soil health by reducing the population dynamics and activity of beneficial microorganisms but also leads to atmospheric and ground water pollution which causes long term health hazards, which are irreversible in nature.[2]

## Biofertilizer Available in the Country

**Table 2.Microbial species available in the country in general for biofertilizer production**

| Nitrogen fixers | Phosphate solubilizers | Potash mobilizers | Zinc mobilizers |
|---|---|---|---|
| Azolla pinnata, Rhizobium sp., Azotobacter chroococcum, Azospirillum lipoferum, Acetobacter diazotrophicus, Derxia gummosa | Azolla pinnata, Rhizobium sp., Azotobacter chroococcum, Azospirillum lipoferum, Acetobacter diazotrophicus, Derxia gummosa | Bacillus sp, Pseudomonas sp | Pseudomonas sp, Bacillus sp , Rhizobium |

Mass scale production of biofertilizers can be realized with these microorganisms as they are in abundance in the natural habitat, easily accessible and would thereby help in creating a potential market for biofertilizers. Institutes that are associated with these organisms in research and development in a pilot scale are ICAR (Indian Council of Agricultural Research), Jawaharlal Nehru Agricultural University, Gujarat Agricultural University (GAU) and, Pondicherry Agricultural University. Premier Institutes that are imparting knowledge of agribusiness to the common are Indian Institute of Management Lucknow, MANAGE, Symbiosis Institute of Management etc.

## List of Biofertilizer Manufacturing Units in India

**Table 3.Different Biotech companies across India producing Biofertilizers[3]**

| | Names of Companies | Production Line |
|---|---|---|
| 1. | Hi Tech Bio Agent Inputs Corporation-India | Bio fertilizers, agro fertilizers, nitrogen biofertilizers |
| 2. | Bhaskar Agrochemicals Ltd.-India | Coated granules, granules, soluble granules, wettable granules, dry seed dressing, dusting powder, emulsifiable concentrate, slurry, oil paste, soluble liquid, soluble powder, suspension concentrate, wettable powder, botanical extracts, plant growth regulator, plant growth promoter |
| 3. | Prabhat Fertilizer & Chemical Works-India | Manufacturers of biofertilizers, zinc sulfate heptahydrate, zinc sulfate monohydrate, zinc sulfate, micronutrient fertilizer, zyme based on seaweed extract, bentonite sulfur 90% (imported), npk 19:19:19 (imported), potassium sulfate |
| 4. | Indore Biotech Inputs & Research (p) Ltd.-India | Bio control agent, bio fungicides, bio pesticides, biofertilizers, organic manure, vermicompost, pheromone trap, pheromone lures, plant growth promoter, nodular, natranu, biohit, herbal insecticides etc |
| 5. | Aaria Bio-lifesciences Research Pvt. Ltd.-India | Biofertilizer, seaweed extract, soil conditioner, plant growth promoters, animal probiotic supplement, agriculture products, animal nutrition, textile products etc |
| 6. | MD Biocoals Pvt. Ltd.-India | Organic manure, organic fertilizer, liquid organic fertilizer, treated granule, biofertilizers, biopesticides, neem products, fertilizer, organic chemicals, nitrobenzene, growth regulators, micronutrient fertilizer, seaweed extract, gibberellic acid, bentonite |
| 7. | Apl Fertilizers and Chemicals Pvt. Ltd.-India | Acetone, gypsum, sodium nitrite, sodium nitrate, skimmed milk powder, ammonium bicarbonate, hydrogen peroxide, phenol crystalline, sulfonated naphthalene formaldehyde powder |
| 8. | Mount Natural Fertilizer Ltd.-India | Natural fertilizer, bio-fertilizer, mount natural fertilizer, mount neem khad, mount aranda khad, mount neem guard (for all types of agriculture use), surmount natural fertilizer (for kitchen garden), mount photophylmount nimbark sar, mount gravya sar, trieco derma virde & phosco, baseco (for spray on crops) |
| 9. | Vision Mark Biotech-India | Biofertilizers, organic fertilizers, bio pesticides, organic pesticides, seaweed extract, micronutrients, humic acid, plant growth stimulator, biopesticides etc |
| 10. | Ananth Bio Fertilizers-India | Biofertilizer, soil conditioner etc |

| | | |
|---|---|---|
| 11. | Mfl, Bellary-India | Biofertilizers like Azospirillum and Rhizobium |
| 12. | Up Agro Fertilizers Limited-India | Biozyme, bentonite granules, seaweeds, amino acids, nitrobenzene, biofertilizers |
| 13. | Bionics Technology-India | Biofertilizers, Biopesticides, Biotechnological Products, Crops, Vegetables, Plants, Fruits, etc |
| 14. | Gujarat Life Sciences (p) Ltd-India | Nitrogenous urea, biofertilizer, urea, ammonia |
| 15. | Flora Group of Companies-India | Banana, biofertilizer, biopesticide. |
| 16. | Prakash Industries-India | Biofertilizer, abtec biofertilizers, abtec biopesticides and organic manures |
| 17. | Eupnoea Technisol Pvt. Ltd.-India | Biopesticides, biofertilizers, biofungicides, micronutrient, plant growth promoter, gear box, shafts, geared motor, planetary gearbox, helical gearbox, bevel gear, spur gear, worm gear, machining components, leaf spring, bolt, nut fasteners, rivet, bushes, seals, o rings, bearings, axle shaft, biofertilizers, liquid fertilizer, humic acid, pesticides |
| 18. | Aureus Technology Group-India | Biofertilizer, Biopesticides, Liquid plant Booster |
| 19. | Varad Fertilisers Pvt. Ltd.-India | Agro products, fertilizer and biofertilizer |
| 20. | Bionspire Corporation-India | Bio fertilizers, soil enhancer, biofertilizer powders, biofertilizers, soil inoculants |
| 21. | Bio Organic Indusries-India | Biopesticide and Biofertilizers |
| 22. | Anmol Agrotech Industries-India | Pesticides products and biofertilizers |
| 23. | M/s Pkb Enterpresis-India | Biofertilizers and Pesticides |
| 24. | Karnataka Agro Chemicals Multiplex Fertilizers Pvt. Ltd.-India | Micro nutrients, pesticides goods, bio fertilizer, bio pesticides and seeds |
| 25. | Ananya Agrotech-India | Vermicompost and Red Worms |
| 26. | Sri Sai Agri Bio Labs Pvt Ltd-India | Biofertilizers |
| 27. | Jaishil Sulphur & Chemical Industries-India | Sulfur wdg 80 %, industrial sulfur |
| 28. | Nature Herbs-India | Biofertilizers, herbal products, forestry equipments, cattle feed, seeds etc |
| 29. | Hindustan Organic chemicals Ltd.-India | Aniline, formaldehyde, nitrobenzene, ortho- nitro- toluene, para -nitro- toluene, meta- nitro- toluene, sulfuric acid 98 %, oleum 24 %, oleum 65% |
| 30. | Migrow Agro Products-India | Bio organic products, biofertilizers, biofungicide, humic acid, seaweed, plant growth promoter etc |
| 31. | Sampurna Bio Agritech Ltd.-India | Biofertilizers and biopesticides |
| 32. | Biocrops Agribiotech-India | Liquid Biofertilizer, Azospirillum, Azotobacter, Phosphobacteria etc |
| 33. | Pasura Bio-tech Pvt. Ltd.-India | Biofertilizers |

| | | |
|---|---|---|
| 34. | Global Enterprise-India | Micronutrient and mix fertilizer (npk), are also manufacturer of pesticides and bio fertilizer |
| 35. | Aramcon biotech-India | Biofertilizers, bio pesticides, pvc granules etc |
| 36. | Lotus Biotech-India | Biofertilizers, biopesticides, biofungicides, plant growth promoters, biostimulents, organic manures, vermi compost, and probiotics |
| 37. | Shree Samarth Agro-India | Biofertilizer |
| 38. | Sri Sai Trading Company-India | Biopesticides, biofertilizer, biofungiside, micronutrient, growth promoter etc |
| 39. | Molecraft Life Sciences-India | Coir Fiber, biofertilizers, biopesticides, plant hormones |
| 40. | Krishak Bharati Cooperative Limited-India | Nitrogenous urea, biofertilizer, urea, ammonia, bio- fertilizers |
| 41. | Neesa Agritech & Foods Ltd.-India | Biofertilizers, biopesticides, tissue tapes etc |
| 42. | Rasoya Proteins Ltd.-India | Oiled cake, soybean oil, soya snacks, ready to eat namkeen, biofertilizers, rice edible oil etc |
| 43. | Anu Biotech International-India | Biofertilizers for agricultural use |
| 44. | Madras Fertilizers Ltd.-India | Biofertilizers |
| 45. | Rovor Bio Technologies (p) Ltd.-India | Biofertilizers |
| 46. | Shivam Bio And Plantation-India | Organic fertilizers, biofertilizers and natural fertilizers |
| 47. | Nagarjuna Agro Chemicals Pvt. Ltd-India | Biofertilizers, biopesticides and micronutrients |
| 48. | Hindustan Organic chemicals Ltd.-India | Aniline, formaldehyde, nitrobenzene, ortho- nitro- toluene, para -nitro- toluene, meta- nitro- toluene, sulfuric acid 98 %, oleum 24 %, oleum 65% |

## Research Institutions and their roles in Research & Development of Biofertilizers across India

The Department has supported programs for developing various bio-fertilizers and technology packages for their mass production and has also focused on the conversion of industrial agricultural wastes into biomanure and on managing the organic waste resources using low capital input protocols without expensive laboratories and sophisticated industrial instruments. Microbial Consortia of Jaypee Institute of Information Technology, Noida project studied plant growth promoting microbes with biofertilizer and bio control properties to build a consortium comprising both bacterial and fungal sp. sampling of microbes was done from the rhizosphere of different plant sp. such as banana, sorghum, millets, pumpkin, potato and grasses. Isolates collected from the rhizosphere of sorghum and grasses were particularly interesting as they were not only withstanding high pH, but also showing tolerance to temperatures in upper mesophilic range of 35-40$^0$C. The antagonistic effects were confirmed to develop a consortium. Manipur University also developed microbial consortia for the effective formulation of optimal strains of plant growth promotion in rice and bio control against rice fungal and bacterial pathogens. Actinomycetes sp., Bacillus sp. and Pseudomonas sp were the focus of the study. After screening of the best strains in lab/greenhouse test, individual or mixtures of strains were subjected to single or multisite pot/field studies to learn feasibility for deployment of consortia of beneficial microorganism for rice. Four isolates were identified. The culture filtrates did not show any inhibition against the fungal pathogens. In vitro seed germination (vigor index) test was performed for three of the selected strains.

## Vermicomposting

Timber lignocellulosic wastes were inoculated with different combinations of the fungi Phanerochete chrysosporium, Trichoderma resei, Aspergillus niger and the bacteria Azotobacter chrococcum. Out of 10 microbial combinations tested for pre-decomposition, the combination of P. chrysosporium + T. resei was found best in terms of lingo-cellulosic degradation prior to vermicomposting. The feasibility of bioreactive Timber Solid Waste Vermicompost (TSWV) had also been validated for the first time.

## Formulation of Mycorrhiza and Agriculturally Important Microorganisms (AIMs)

The Energy Resources Institute (TERI), New Delhi revalidated the PGP/BCA strains such as actinomycete isolates LSCh-10C, NRPI-18 and NRPI-18 and NRPI-26 and putative Bacillus isolates CHDR. They established the co-habitation of AIMs with Arbuscular Mycorrhizal Fungi (AMF) to synergize their beneficial effects by developing a single bio-inoculants product that can improve plant growth by supplementing with nutrients. Six new uncultivable endobacterial sequences were detected by the DGGE analysis and 5 more were found after cloning of 16S product directly. Endobacterial diversity comprised of both Bacilli related species as well as Bacterium-Like Organisms (BLOs). In case of termicomposting, Pondicherry University, Pondicherry has completed the systematic survey of termite species with the species available and their relative abundance has been established in a proper fashion. Two types of multi-compartment termireactors were designed. The multiple compartments would be able to use different substances simultaneously at each location and see the relative preference of termites at that location for different feeds. Study has been undertaken towards captive colony development and preliminary designs of alate traps, in situ termireactors, and termite harvesters. Pondicherry University had set up an interactive web-based repository of all the information and the resources of information on termite distributions, niche, habitat, biology, substrate preference, role in natural environments, control methods etc.[4]

## Blue Green Algae Commercialization in North Eastern India

Blue green algae are a group of gram negative photosynthetic prokaryotes mostly known as Cyanobacteria which has drawn worldwide attention for nitrogen fixing ability and their use in agriculture. BGA are very common in Indian rice fields. The study is focused towards developing ecofriendly technique for mass production and suitable bio-inoculum development for field application of BGA strains. For that purpose, three BGA strain namely Anabaena torulosa, Anabaena doliolum and Calothrix marchica were isolated from selected rice field of Assam, North East India.

Growth behavior and potentiality of all the three strains were studied in terms of their biomass production, chlorophyll-a and total chlorophyll content, packed cell volume (PCV) and their production of IAA like substances. The Intrinsic antibiotic resistance profile (IARP) test and compatibility study among the three aforementioned BGA isolates were also carried out for their efficient growth and biomass production for application and development of biofertilizer technology. Three bio wastes namely paddy straw, sugarcane trash and water hyacinth were analyzed for substrate preparation. It was Anabaena torulosa which showed maximum biomass yield of 18.33 mg/100ml and N-content of 10.16% was obtained when paddy straw was taken as substrate. Again paddy straw showed the best result of 28.16mg/100ml and N-content of 20.33%, when composite inoculation of all the three stains was considered. Based on these findings, an integrated BGA immobilized inoculum was also formulated Luffa cylindrica with sugarcane trash which is locally known as 'bhol'. The experiment conducted was aimed to achieve suitable biofertilizer production at a very low cost using the cheapest substrate which is far superior to harmful chemical fertilizers available in market. This total phenomenon enlightens us on the efforts to commercialize abundantly found BGA in north eastern states of India.[5]

## Privatization of R&D in India and Agricultural Innovation in Fertilizers

Private R&D expenditure within the fertilizer industry has grown slowly, rising from $6.7 million in the 1990s to only about $7.9 million in 2008/09. A few firms conduct most of the research. In 2009, Nagarjuna and Tata Chemicals conducted 75 percent of private research, and Tata Chemicals accounted for most of the growth. Among government- owned firms and cooperatives, Gujarat State Fertilizers and Chemicals lead R&D. The fertilizer industry also has the lowest research intensity of all input industries, and its research intensity is declining with every year. In 2000, research intensity of private firms was about 0.22 percent, and it declined to 0.12 percent in 2009. Research intensity of government- owned firms declined sharply from 0.08 percent to 0.03 percent over the same period. Fertilizer research efforts have recently focused on developing fertilizers that combine standard nitrogen, phosphorous, and potassium (NPK) with minor and micronutrients to meet the needs of specific regions in accordance with their geographical limitations. For example, Tata Chemicals established a new crop nutrition and management research program in Aligarh in 2006 that included 10 scientists, 20 agronomists, and a research budget of about Rs. 20 million in addition to scientists' salaries (Tata Chemicals, pers. comm. 2009). This center designed and developed customized fertilizer grades for rice, wheat, maize, potato, and sugarcane, and carried out other R&D related to foliar applications of nutrition. Another rapidly growing area of research is water-fertilizers. Coromandel Fertilizers in

South India is conducting research on specialty nutrients for niche markets, including water-soluble organic and micronutrient-based fertilizers. Globally, there has been little innovation and R&D in the fertilizer industry. Subsidies, price controls, and regulations on new products have meant that, until recent deregulation, there was little incentive for research. Government subsidies reserved for Indian firms made it virtually impossible for foreign companies to enter the Indian fertilizer industry except with some specialty products. Innovation and research on biofertilizers and organic fertilizers has grown substantially in recent years. Sales and innovation in this area have increased so much that it was brought under government control in 2005. All biofertilizers now have to be tested for efficacy and have to be approved by the government in order to control quality and prevent fraud. TERI has been a leader in research on biofertilizers and has commercialized a number of products in joint ventures with commercial fertilizer companies. Its main product is arbuscular mycorrhiza. International firms such as Novozymes are also entering the market. Sales of phosphate solubilizing bacteria (PSB) in particular are soaring because the product works on any crop. Companies that sell phosphorus fertilizers tend to push PSB because it improves the performance of their chemical fertilizers. Currently, at least 10 fertilizer companies are working on PSB and related formulations (Fertilizer Association of India 2009) towards commercialization.[6]

## Distribution of Biofertilizer and Chemical Fertilizer in India

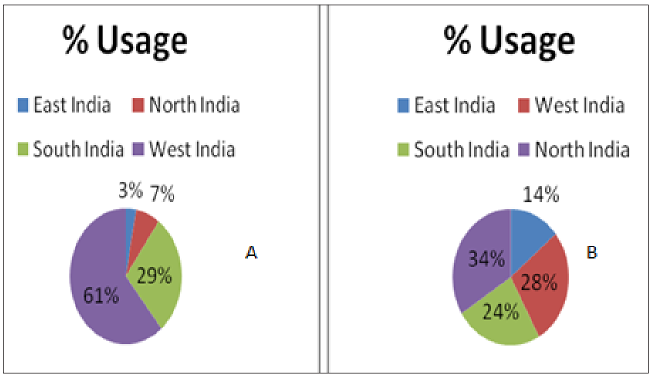


**Figure 2.(A) Usage of Biofertilizers across India (B) Usage of Chemical fertilizers across India**

It may be thereby said that India being the yardstick for so many agricultural practices, which are diverse in nature, is lacking the proper infrastructure. The aforesaid industries and their production are not sufficient to provide a full scale alternative to the existing and widely used chemical fertilizers.

There is a huge gap between industry and academia resulting in a paucity which is disadvantageous for the future generations to come. Mass scale applications are going on in the states of Tamil Nadu, Karnataka, Kerala, Punjab, Haryana, Himachal Pradesh etc. The country and its people still need to go a long way to get independence from harmful chemical fertilizers.[7]

## Iran

The country has a potential farmland capacity of one-third of its total land but lack of soil quality and adequate water distribution has made it impossible for most parts of Iran to under cultivation. Only 12% of the total land area is under cultivation, of which only one-third of the land is properly irrigated. The western and north western parts of Iran are most fertile in nature besides which the food security index of Iran is 96%. At the end of the last century, one-fifth of Iran's Gross Domestic Product (GDP) depended on agriculture employing a good number of workforces. Most of the farming lands are less than 10 hectares leading to a huge migration of the population towards the cities. After revolution in the year 1979, many people occupied large land areas and are the disputed owners of those cultivable lands but this has led to the some positive agricultural research in and around the country.[8]

## Research & Development in the Field of Biofertilizers

The researchers of Iranian universities have come up with good solutions for their existing problems and some of the few are mentioned below:

In order to study the effect of Mycorrhiza and Azospirillum on the germination characteristics of wheat cultivars, an experiment was conducted in the research station of Shahid Chamran University of Ahvaz, Iran in 2012-13. The experimental design was factorial, based on randomized complete blocks design with three replications. The treatments including of Mycorrhiza fungi were in three levels (no use of strain and using strain Glomus intraradices and Glomus mossaae), bacteria Azospirillum lipoferum in the two-level (non-inoculated seeds and inoculated seed) and wheat cultivars in three levels, Chamran (bread wheat), Dena and Behrang (durum wheat) varieties. In this experiment, in standard germination test, traits of seed germination index and seed germination characteristics have been measured. The results showed Mycorrhiza and Azospirillum increased seed germination percent and germination rate of wheat cultivars. Azospirillum was more effective than Mycorrhiza showing highest of seed germination percent and germination rate was obtained from the treatment bread wheat with G. intraradice and A. lipoferum.[9]

Further, a research was performed to check how waterlogging restricts canola growth via different physiological changes. The objective of this work was to compare the effects of the foliar and seed application of two biofertilizers on some physiological and morphological responses in canola plants (Brassica napus L. cv. Hayola 401) under waterlogging stress conditions. Plants at 5-leaf stage were exposed to flooding conditions for two weeks. Two biofertilizers; AAP (Azotobacter chroococcum, Azospirillum spp. and Pseudomonas spp.) and APB (Azospirillum spp., Pseudomonas fluorescens and Bacillus subtilis) were applied by seed inoculation or foliar spray at different times i.e. before waterlogging, after waterlogging and, before and after waterlogging. The results showed that the flooding stress significantly decreased the dry weight and length of the shoots and roots. The activity of Superoxide Dismutase (SOD), Catalase (CAT), and Peroxidase (POX) were reduced, whereas lipid peroxidation and ethylene production in the leaves were increased under waterlogging stress. The adverse effects of the flooding stress were significantly alleviated by the seed inoculation and foliar application once (before the stress) of both biofertilizers compared to the waterlogged control. However, among two methods, inoculating the seeds with the biofertilizers is cost efficient and advisable to alleviate waterlogging damage in canola. This experiment has helped save canola, a very profound source of edible oil, found in most parts of Iran.[10]

Now, again in order to evaluate the effects of a biofertilizer containing Azospirillum and Azotobacter inoculants on phenology and growth of sunflower cultivars in the region of Sanandaj in Kurdistan province (west of Iran), an experiment was conducted using a split-plot layout with randomized complete block design in three replications. Two levels of application and non-application of biofertilizer were compared in main plots. Four cultivars (Azargol, Euroflor, Lacomka & Feverit) were applied as sub-plots. The results indicated that inoculants application significantly affected growth stage intervals. Number of days to star shape stage, vegetative stage duration, number of days to flowering end, reproductive stage duration, grain filling duration and the total duration of plant growth were significantly increased by using biofertilizer as compared with non-application of biofertilizer. There were significant differences between cultivars with respect to duration of growth stages. Growth stage intervals of Azargol hybrid were longer than that in other cultivars and the shortest period of growth stages was recorded by Lacomka cultivar. Morphological traits such as plant height, head weight, stem diameter, stem weight, hollow diameter and head diameter were not affected by biofertilizer and cultivar. However the crop growth was promoted as the result of biofertilizer application.[11]

Nitrogen different levels and biofertilizers effects were studied on growth and yield of canola in Qazvin province. An experiment was conducted in a split-plot design as base of randomized complete block design with four replications. Treatments included 3 levels of nitrogen (0.75 and 150 kg $ha^{-1}$) and bio-fertilizers on four levels (not inoculation, Azotobacter, Azospirillum and with inoculation combined). The results showed that nitrogen had significant effect on the number of seedlings per plant, seed yield, 1000 seed weight, seed yield and plant height. So that with the increased use of nitrogen fertilizer, all of these traits increased and the combined use of also increased on seed yield. Interaction of nitrogen and biofertilizer affected the seed yield, significantly. Use of nitrogen fertilizer in amount of 2195 Kg $ha^{-1}$ produced the highest seed yield when seeds were inoculated by biofertilizers. One hundred and fifty N (kg $ha^{-1}$) and non- inculcation produced the highest seed yield. The combined use of biofertilizers also was statistically superior to other treatments. However, the highest yield was received with 150 N (Kg $ha^{-1}$) but it seems using of 75 N (kg $ha^{-1}$) and inoculation of Azospirillum and Azotobacter produced suitable yield (20% loss).[12]

## Biotechnology Institutes in Iran promoting Biotechnology and Biofertilizers

**Table 4.Biotechnology Institutes in Iran promoting Biotechnology and Biofertilizers**

| S. No. | Name of Institute |
|---|---|
| 1. | Center for Innovation & Technology Cooperation (CITC) |
| 2. | National Committee for Policy Making in Medical Biotechnology |
| 3. | Agricultural Biotechnology Research Institute of Iran (ABRII) |
| 4. | Biotechnology Department of Pasteur Institute of Iran |
| 5. | Iranian Research Organization for Science & Technology (IROST) |
| 6. | National Research Center for Genetic Engineering and Biotechnology (NRCGEB) |
| 7. | Razi Vaccine & Serum Research Institute |
| 8. | Royan Institute |
| 9. | Avicenna Research Institute |

## Biofertilizer Products and Infrastructure in Iran

### Phosphate Biofertilizer BARVAR-2

BARVAR-2 phosphate biofertilizer contains two types of Phosphate Solubilizing Bacteria (PSB) Barvar-2 Biofertilizer and Nitro Kara Biofertilizer.

It has a high Phosphate solubilizing competency and, genetic stability. Environmental fitness, colony formation rhizosphere, long shelf time, simple application methods, inexpensive shipping, compatibility with other chemicals, reduction of environmental pollution and significant increase in the yield are some of Barvar-2 biofertilizer features. In practice, Barvar biofertilizers consistently increase the yield of crops by 10 to 50 percent; while reducing the need for chemical Phosphate fertilizer by over 50 percent.

## Nitro KARA Biofertilizer (Natural Nitrogen for your Plants)

Nitro Kara is a Nitrogen fixing biofertilizer. Nitrogen is a major nutrient for all plants. Nitro Kara has highly efficient nitrogen fixing bacteria called Azorhizobium caulinodans which was isolated from nature. Azorhizobium caulinodans produces growth promoting substances such as Indole Acetic Acid (IAA) and Gibberellins, and promotes root proliferation which increases the rootlet density and root branching.

Its advantages are non-chemical composition, efficiency of 1 kg or liter of KARA biofertilizer is equal to 100 kg urea fertilizer, reduces the need for artificial chemicals in fields and gardens, eco-friendly and possesses no danger to the environment; increases water use efficiency, promotes the growth of plants, enhances seed germination and plant growth, increases the production of crops, provides protection against drought and certain soil borne diseases, improves soil structure and water holding capacity; restores natural soil fertility, safe for human, pets and wildlife.[13]

## Biofertilizer Infrastructure

No exact figures are available for the production or use of manure in the country. Unofficial sources put the production of cattle and poultry manure at 31 million tons. It is estimated that about 30 percent of this amount is burnt as fuel by farmers who cannot afford other types of fuel. Out of the remaining 70 percent, some part is just disposed of and the benefit of the nutrient and organic content is lost. Currently some private companies are producing biofertilizers and compost. The municipal corporations of major cities too are involved in the production of compost and vermi-compost. There is no record of their production and sales. In the context of increasing the yields of food crops by promoting balanced nutrient application, the production and application of biological fertilizers have been encouraged during the last four years. Three main private companies now produce biofertilizers. The main types of biofertilizers produced include: Thiobacillus (sulfur-oxidizing bacteria) along with zinc, Granulated Phosphate Solubilizing Bacteria and Azotobacter (a free living nitrogen fixer). There are, however, distribution and marketing problems, especially in view of the limited shelf life of these materials. For example, one producer of Azotobacter inoculums produced two million one-kg packages of the material in three months, but unfortunately the company ran into problems of timely distribution and application. Another producer reports that more than 30 percent of its Azotobacter packages are still in the storage facilities of the company in Kerman. Micronutrient deficiencies are a widespread health hazard, especially with regard to iron, vitamin A and zinc, particularly in developing countries. The World Health Organization (WHO) announced in 1996 that the molar ratio of phytic acid to zinc (PA/Zn) should not exceed 25, otherwise the absorption of minerals (including zinc), contained in our diet (especially bread), becomes problematic. Three studies on the level of zinc in the body among the young population in Iran indicate a serious problem of zinc deficiency. Research results indicate that a balanced application of nutrients (phosphate rates based on soil tests) and zinc sulfate on wheat fields lowers the PA/Zn ratio in the wheat grain and consequently improves the rates of absorption of minerals through the digestive system. Increasing the levels of grain phosphorus causes an increase in the phytic acid content. In general, unbalanced fertilization (high levels of phosphorus and low rates of zinc) increases the PA/Zn ratio while the application of zinc sulfate increases the concentration of zinc in the grain and decreases the level of phytic acid. Investigations on the effect of zinc application on various wheat varieties have shown that, in addition to reducing the concentrations of phytic acid in the wheat grain, yields have also been improved. To improve crop yield in the cultivated areas, gypsiferous soils must be supplied with sufficient micronutrients, particularly zinc. Among other options, utilization of mycorrhiza fungi or symbiotic bacteria, which do not need organic matter to survive, can be used to increase the amount of available P in such problem soils.

**Table 5.Subsidized price of biofertilizers in Iran as of 2004[14]**

| Type of fertilizer | Price (Rial/ Kg) | Type of fertilizer | Price (Rial/ kg) |
|---|---|---|---|
| Urea | 450 | Granulated organic sulfur | 465 |
| AN | 375 | Microbial phosphate fertilizer | 5140 |
| AS | 425 | Azotobacter inoculant | 5140 |
| DAP | 640 | Chickpea Rhizobium inoculant | 5140 |
| TSP | 515 | Bean rhizobium inoculant | 465 |
| SSP | 260 | -- | -- |
| Potassium sulfate | 535 | -- | -- |
| MOP | 410 | -- | -- |
| Potassium nitrate | 470 | -- | -- |
| Compound crops | 575 | -- | -- |
| Compound orchards | 645 | -- | -- |

## Iranian Government Policies on Biofertilizer Distribution

Rural farm cooperatives, employing agricultural specialists and technicians, can serve as effective organizations for promoting a sustainable system of agriculture. Farm cooperatives have always acted as lead groups for projects that are designed to improve farming in general and the application of fertilizers, pesticides and herbicides in particular. Soil laboratories are serving a number of rural farm cooperatives like those of Sabzevar and Kerman. Currently, more than 1000 rural farm cooperatives have been organized across the country. They cover some 3 million hectares of farmland and claim more than 260000 farmer members in more than 4600 rural communities. Crop yields per unit area of farmland in communities that are served by cooperatives are often higher than the yields obtained in the adjacent farms, or in their provinces or the country as a whole. Moreover, the production of field and horticultural crops has increased considerably in those areas. Central Organization of Iranian Rural Production Cooperatives (COIRPC) aims at the development, extension and strengthening of the cooperatives thus improving marketing and developing rural cooperation services activities. The activities of this organization include teaching, training in management and other courses, personnel training, accounting, purchase and safe storage of the produce by companies and cooperatives and their distribution to appropriate markets. This organization also supervises the construction of buildings and utilities such as storehouses, cold storage, shops, factories, offices etc. They organize exhibitions to introduce farmer produce to the market, provide technical assistance and support services. They deal with insurance, the economic supervision of other cooperatives and provide technical and consultancy assistance concerning publicity and marketing.

The rural and agricultural cooperative network has 4935 branches including the Rural Women's Cooperatives, 340 units, 10,693 shops, and 11,794 units for the distribution of fuel. With around 5 million members, the network covers 98 percent of the villages of the country, with a population of approximately 25 million people. The "Farmers' House" was established in order to protect the right of the farmers. Comprising of agriculturists, farmers and scientific personnel, it was created in order to represent farmers' interest to relevant officials in the government. Farmers' House endeavors to develop the agricultural sector in political, social, economic and cultural fields. It aims to eradicate poverty in the rural sector by emphasizing the necessity of legislation and the prevention of the invasion of agricultural land by other sectors. It also aims to convert traditional agriculture into an advanced and sustainable agriculture, using appropriate modern technology with the rational use of agricultural inputs. The Agricultural Support Services Company (ASSC) is responsible for providing and distributing mineral fertilizers, pesticides, seeds and improved plant varieties. It has played an important and vital role in increasing the quality and quantity of agricultural products. ASSC has distributed 3.1 million tonnes of mineral fertilizers annually on average in the past three years. This compares with an average of 2 million tonnes of mineral fertilizers in the decade prior to 1990. It also distributes pesticides and seeds.

## Fertilizer Prices and Subsidies

The Government of Iran has subsidized all mineral fertilizers for the past three decades. The amount of subsidy two years ago, when the total production was less than three million tonnes, was US$70 million. The subsidy was paid to the Iranian petro-chemical industry, to permit it to sell fertilizers at reduced prices. Due to an increase in the amount of fertilizer used, i.e. 3276 and 3700 million tonnes in the years 2002 and 2004 respectively, and the increased cost of fertilizers, the fertilizer subsidy given by the government now amounts to more than about US$200 million. The subsidy on fertilizer may contribute to the smuggling of fertilizers to neighboring countries (Statistics and Information Technology Office, 2001/2004)[14]. The government of Iran has understood its added responsibility in promoting agriculture with worthy potential alternatives so as to boost the economy and grow at a rate of more than 6% in terms of GDP annually and thereby curb the all in all crude oil and gas export to other countries to alleviate its foreign exchange reserves.

## Bangladesh

Bangladesh is primarily an agrarian economy. Agriculture is the single largest employment and production center of the country. According to the data released by IMF (International Monetary Fund) and as of 2010, agriculture consists of 18.6 % of the total GDP of the country and employs 45% of the total labor force. It has huge impact on food security, poverty alleviation, human resources development and so on, affecting the whole economy. Although rice and jute are the major crops, wheat holds a much larger importance in Bangladeshi economy. Tea is also produced in the north east. With over 35.8 million tons of rice produced in 2000, it is the principle crop undoubtedly, but at the same time national sales of different types of pesticides classified for specific applications increased by leaps and bounds such as Carbofuran, Synthetic Pyrethroids and Malathion exceeded over 13,000 tons. This not only poses a serious threat to the environment but also costs dear to the poor farmers of the country. Bangladesh Rice Institute has started working through NGO's to spread awareness amongst farmers to lessen use of chemical pesticides and increase use of biofertilizer to generate maximum crop production by sustainable development of man and nature.[15]

## Biofertilizer Development in Bangladesh

Biofertilizer is becoming very popular in Bangladesh compared to chemical fertilizers because of its easy availability and ecofriendly nature. The following organizations are involved in biofertilizer activities in the country: Bangladesh Institute of Nuclear Agriculture, National Institute of Biotechnology, Bangladesh Agricultural University, Bangladesh Agricultural Research Institute etc.

## Ongoing Research Proceedings

1. Rhizobial biofertilizer for pulse and oil seed legume (lentil, chickpea, mung bean, cowpea, black gram, groundnut and soybean): Intensively studied and best developed in Bangladesh and is a mature technology.
2. Azolla for wet land Boro rice: Mature technology is still going on at plant scale (not in practice).
3. Phosphorus solubilizing bacteria (PSB): On- farm evaluation going on for mass scale applications.
4. Azospirillum/ Azotobacter/ blue green algae: Evaluating at field condition and is a regular biofertilizer in daily use.
5. Mycorrhiza: Evaluating at pot and field condition.[16]

## Biofertilizer Manufacturer in Bangladesh

**Table 6.Name of biofertilizer manufacturers in Bangladesh[17]**

| Manufacturer name | Products |
|---|---|
| Quantum leap | Organic biofertilizer |
| Prostar Group | Anaerobic Filter Tank |
| Sea Resource Company | Biofertilizer |

## Role of Bangladeshi Government in Spreading Biotechnological Awareness

Bangladesh has installed a chain of networks to ensure the feasibility of the implementation of all rules and regulations pertinent to an all round development of biotechnology in the country. The Committee on Biotechnology of Bangladesh (NTCBB) is under the prime minister as chairperson. Biosafety policy guidelines and related aspects of biotechnology issues have been approved and the laws are in the process of being promulgated. Being a party to the Cartagena Protocol on Biosafety, proper biosafety measures are regulated by the appropriate authority as stated. Although there are no laws yet for biosafety of GM crops and food, relevant laws on agriculture, medicine, food, import, trade, and environment may suffice. The second powerful body, the National Executive Committee on Biotechnology of Bangladesh (NECBB) is also functioning under the Principal Secretary to the Prime Minister. Five National Technical Committees (NTC) on Biodiversity, Biosafety, Plant Biotechnology, Animal and Fisheries Biotechnology, and Medical Biotechnology are also operating under the secretaries of the respective ministries. The Task Force approved all guidelines and policies developed by the concerned ministries and NTCs in 2006. The Ministry of Environment and Forests (MoEF) is the national focal point to implement the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CBD). National Technical Committee established the data for Bangladesh, the world's largest delta with only 55,598 square miles. India borders almost two-thirds of the territory. It is bounded by Burma to the east and south and Nepal to the north. Despite being small in size, it is home to nearly 130 million people with a population density of nearly 2000 per square miles, one of the highest in the world. About 85% people live in rural villages and 15% in the urban areas. The country is mainly agriculture based where 80% of the people depend on this industry. Fertile alluvial soil of the Ganges- Meghna-Brahmaputra delta coupled with high rainfall and easy cultivation favors agricultural development. Rice is the staple food while potato, sugarcane, jute, wheat, and corn are other major crops. Bangladesh is a promising country in South Asia for biotechnology commercialization in the near future. It is a party to the Cartagena Protocol on Biosafety and has developed a series of enabling and regulatory frameworks for genetically modified crops management. Research is being done on Golden Rice, Bt brinjal, and blight resistant potato which have gone through glasshouse and two years of field trial. Bangladesh is heavily strategizing communication in commercialization of Biotech Crops on Biosafety (NTCB) to ensure environmentally safe management of modern biotechnological development including Research and Development (R&D), introduction, use, and transboundary movement of Living Modified Organisms (LMOs). They also developed the National Biosafety Framework (NBF) for overall guidance of biotechnological research in the light of biosafety protocols. The Biosafety Core Committee (BCC) assists the NTCB which in turn is supported by the Institutional Biosafety Committee (IBC), Field Level Biosafety Committee (FBC), and Biological Safety Officers (BSO) in each research establishment of the country. In a circulation released in 2002, the Bangladesh government instructed all research institutes to open Biotechnology and Genetic Engineering Departments. The National Institute of Biotechnology (NIB) was also established. The Ministry of Science and Information and Communication Technology (MOSICT) in the last ten years has continuously provided a modest amount of fund for biotech research. Recently, scientists proposed that government set up a separate permanent department in the MOSICT to facilitate biotech activities in the country.[18]

## China

Agriculture is of paramount importance for Chinese economy. It employs round about 300 million people in the country.

## Development and Application of Biofertilizer in China

The Republic of China is a subtropical island characterized by high temperatures and heavy rainfall. Intensive agriculture practices have served as a strong foundation for the Republic of China's commercial and industrial "economic miracle." In recent years, agrochemicals (pesticides and fertilizers) have been extensively applied to obtain higher yield. Intensive application of agrichemicals leads to several agricultural problems and poor cropping systems. Farmers may use more chemical fertilizers than the recommended levels for some crops. Excessive application of chemical nitrogen fertilizer not only accelerates soil acidification but also risks contaminating groundwater and the atmosphere. Organic fertilizers offer a safe option for reducing the agrochemical inputs. Biofertilizers have been developed in several laboratories in the Republic of China over the years. Microorganisms including rhizobium, phosphate-solubilizing bacteria, and Arbuscular-Mycorriza (AM) fungi are continuously being isolated from various ecosystems and their performance in laboratory and field conditions are being assessed. The extensive research program over the years on beneficial bacteria and fungi has resulted in the development of a wide range of biofertilizers which not only fulfill the nutrient requirements of various crop species but also increase crop yield and nutrient composition. Numerous experiments in greenhouses and in field conditions have shown that many different crops respond positively to microbial inoculations. In particular, successful rhizobial inoculants were applied to leguminous plants and AM fungi for muskmelons in order to increase yield. Multifunctional biofertilizers were developed to reduce chemical fertilizer application by about one-third to one-half. Enhancement and maintenance of soil fertility through microorganisms will be an important issue in future agriculture. Long-term conservation of soil health is the key benefit of biofertilizers, equivalent to the most sustainable form of agriculture.

## Business Potential of Biofertilizers and Agro-Biotechnology in China

In applied microbiology, biopesticides and biofertilizers are the two hot items in agriculture. Several major companies, such as Yuen-Foongyu Paper Co., Tai-En Co., and Biontech Inc., have begun to produce and merchandise these products under their own brands. Although at present the total value of this new industry is only about 0.5%-1% of the total traditional pesticide market, it is growing at the rate of 10%-15% annually. Recently, a brand called Biowork (Bacillus subtilis) has opened a new market in Japan, and some products of Streptomyces have created an annual value of 10-20 million in the domestic market. Several fungi and bacteria have been studied for their potential as biofertilizer, including the genera Pseudomonas, Bacillus, Thiobacillus, Penicillium, and Aspergillus. There have been some good products marketed by different companies that have been quite well accepted by farmers. Other products of agricultural biotechnology with high market potential will likely result from genetic engineering, including genetically modified organisms (GMOs) for producing specific bio products, detection kits derived from recombinant DNA techniques, transgenic plants, and transgenic animals. There has been a lot of effort to promote developments in this field of research, with lots of ongoing researches. One of the important achievements is the transgenic papaya resistant to papaya ring spot virus developed by Chung-Hsin University about 10 years ago, which passed environmental risk assessment in 2000. It must still undergo food safety assessment before being marketed. There are several transgenic crops, including rice, broccoli, potato, and tomato, which are currently in the process of environmental risk assessment at the Taiwan Agricultural Research Institute and the Asian Vegetable Research and Development Center but are not yet subject to food safety assessment.[19]

## Research Proceedings in the Country

The study below shows a data analysis of different plant growth promoting microbial strains which shows certain noticeable and feasible change in terms of productivity and value for applicative purposes. Some multifunctional biofertilizers were developed. The test strains were (1) Klebsiella pneumonia; (2) Penicillium oxalicum; (3) Bacillus mucilaginosus; (4) Trichoderma longbrachiatum; (5) Trichoderma konigii; (6) Trichoderma citrinoviride; (7) Bacillus mucilaginosus; (8) B. megaterium; (9) B. megaterium (ATCC14581); (10) B. circulans. Test crops were soybean, corn and rice. Test soils were Chao soil and Dark Brown Chernozemic soil. We got 10 kinds of high effective multifunctional biofertilizers. The results showed that the combination of Azotobacter chroococcumm, Penicillium oxalicum and Bacillus mucilaginosus with rice plant in Dark Brown Chernozemic soil achieved a high biomass yield. The combination of P. oxalicum, T. longbrachiatum, T. citrinoviride, and T. konigii with soybean in Chao soil got the highest biomass yield. The combination of P. oxalicum, T. longbrachiatum, T. citrinoviride, and T. konigii with soybean in Dark Brown Chernozemic soil was the best one. The combination of K. pneumoniae, P. oxalicum, B. mucilaginosus, T. longbrachiatum, T. citrinoviride, and T. konigii with corn in Chao soil had a marked effect on corn biomass.

## The Results are Displayed in the following Table

**Table 7.Changes in soil productivity after application of plant growth promoters20**

| Strain combination | crop | Soil type | Dry wt.(g) | Fresh wt.(g) | |
|---|---|---|---|---|---|
| Klebsiella pneumonia+ Trichederma longbrachiatum+ Trichoderma konigii+ Trichoderma citrinoviride | Soybean | Chao soil | 3.37 | 17.0 | |
| Bacillus mucilaginosus Trichederma longbrachiatum+ Trichoderma konigii+ Trichoderma citrinoviride | Soybean | Chao soil | 3.34 | 18.5 | |
| Bacillus mucilaginosus Trichederma longbrachiatum+ Trichoderma konigii+ Trichoderma citrinoviride | | | | | 18.54.18Dark brown chernozemic soilSoybean |
| Klebsiella pneumonia+, Penicillium oxalicum+ Bacillus mucilaginosus +Trichoderma longbrachiatum+ Trichoderma konigii+ Trichoderma citrinoviride | | | | | 4.530.67Chao soilCorn |
| Penicillium oxalicum +Trichoderma longbrachiatum+ Trichoderma konigii+ Trichoderma citrinoviride | | | | | 4.310.53Dark brown chernozemic soilCorn |
| Azotobacter chroococcumm + Penicillium oxalicum+ Bacillus mucilaginosus | | | | | 17.53.31Dark brown chernozemic soilRice |
| Trichoderma longbrachiatum + Trichoderma citrinoviride+ Trichoderma konigii | | | | | 15.32.87Dark brown chernozemic soilRice |

## Biofertilizer Manufacturers in China

**Table 8.Biofertilizer companies in Republic of China and their products[21]**

| Name of the manufacturer | Products |
|---|---|
| Xi'an Citymax Agrochemical Co., Ltd. | Liquid Organic Fertilizer, Liquid NPK Fertilizer |
| Bio Plus Fertilizer | Bio Organic Fertilizer, Bio Green Fertilizer |
| Weifang Dongxing Chitosan Factory | Bio Fertilizer, Humin Rich, Humic Acid Pellets |
| Shenyang Humate Technology Co., Ltd. | Bio Fertilizer, Humin Rich, Humic Acid Pellets |
| Agrolink Internation Co., Ltd. | Phosphate bio fertilizer |
| Bio life- mushy seaweed fertilizer | Seaweed Fertilizer |
| Yantai Jiate Bio-Tech. Co., Ltd. | Agriculture liquid bio fertilizer,100% water soluble seaweed extract liquid |
| Qingdao Seawin Biotech Group Co., Ltd. | Seaweed organic granular bio fertilizer |
| Qingdao Jingling Ocean Technology Co., Ltd. | Rich Humic Acid And Fulvic Acid Organic Liquid Bio Fertilizer, Organic Liquid Bio Fertilizer |
| King Deng (Beijing) Technology Co., Ltd. | Rich Humic acid and Fulvic acid organic liquid bio fertilizer, organic bio fertilizer for chili |
| Guangxi Penshibao Co., Ltd. | organic bio fertilizer for chili |
| Xiamen Vastland Chemical Co., Ltd. | Bio Organic Fertilizer, Liquid Bio Fertilizer |
| Beijing Leili Marine Bioindustry Inc. | Bio Compost Fertilizer, Bio Fertilizer Plant, Bio Fertilizer Bacteria |

| | |
|---|---|
| Xingtai Sinobest Biotech Co., Ltd. | Bacillus mucilaginosus Potassium bacteria bio fertilizer Organic Fertilizer, Algae Refined Fertilizer, Biological Fertilizer |
| Qingdao Runfeng Means Of Agricultural Production Co., Ltd. | Potassium Fulvic Bio Fertilizer, Biochemical Fulvic Acid Potassium Bio Fertilizer |
| Shandong Chuangxin Humic Acid Technology Co., Ltd. | Biochemical Fulvic Acid Potassium bio fertilizer, seaweed bio fertilizer |
| Qingdao Yuda Century Economy And Trade Co., Ltd. | 80%min Fulvic Acid Powder Bio Fertilizer |
| Humate (Tianjin) International Limited | 80%min Fulvic Acid Powder Bio Fertilizer, Bio Fertilizer for wheat, maize, sunflower, sugar beet |
| Qingdao Chengzhihe Industrial And Trade Co., Ltd. | Seaweed foliar fertilization liquid bio fertilizer |
| Qingdao Future Group | High quality granular bio fertilizer |
| Weifang Ocean Trading Co., Ltd. | Bio Fertilizer, Seaweed Extract Fertilizer, Seaweed Bio Fertilizer |
| Yantai Swide Biological Technology Co., Ltd. | Seaweed liquid bio fertilizer, Liquid Bio Fertilizer Bulk Liquid Fertilizers, Bio Organic Fertilizer |
| .Xi'an Tbio Crop Science Co., Ltd. | Seaweed Extract Bio Fertilizer, Sargassum Seaweed Fertilizer, Seaweed Foliar Spray Fertilizer |
| Shanghai Redbrillian Chemical Co., Ltd. | $P_2O_5$ 28% seabird guano phosphate bio fertilizer |
| Shenyang Humate Technology Co., Ltd. | Potassium Humate Deflocculation Bio Fertilizer |

## Chinese Government Initiatives

Bio-agriculture is mainly used by the plant/animal feed and livestock industries. Under the 11th Five-Year Plan, bio agriculture development has focused on the commercialization of new hybrid/ genetically-modified crops, and on production of bio-fertilizers, feed additives, veterinary vaccines, and diagnostic reagents. In July 2008, the Chinese State Council announced plans to spend US$ 3.5 billion over the next 12 years to promote the commercialized planting of three genetically modified crops- wheat, barley, and corn. China is already an international leader in hybrid rice and insect-resistant cotton, and has successfully genetically modified and cloned animals (e.g. ox, sheep). In addition to genetically modified plants and animals, China has also commercialized five new veterinary vaccines and drugs.[22]

## Pakistan

Pakistan's principal natural resources are arable land and water. It is estimated that about 25% of Pakistan's accounts for about 21.2% of GDP and employs about 43% of the labor force. In Pakistan, the most agricultural province is Punjab where wheat and cotton are the most grown crops. Some people also have mango orchards but due to some problems like weather, they're not found on a large scale. The most important crops are wheat, sugarcane, cotton, and rice, which together account for more than 75% of the value of total crop output. Pakistan's largest food crop is wheat. In 2005, Pakistan produced 21,591,400 metric tons of wheat, more than all of Africa (20,304,585 metric tons) and nearly as much as all of South America (24,557,784 metric tons), according to the FAO. Pakistan has also cut the use of dangerous pesticides dramatically. Pakistan is a net food exporter, except in occasional years when its harvest is adversely affected by droughts. Pakistan exports rice, cotton, fish, fruits (especially oranges and mangoes), and vegetables and imports vegetable oil, wheat, pulses and consumer foods. The country is Asia's largest camel market, second largest apricot and ghee market and third largest cotton, onion and milk market. The economic importance of agriculture has declined since independence, when its share of GDP was around 53%. Following the poor harvest of 1993, the government introduced agriculture assistance policies, including increased support prices for many agricultural commodities and expanded availability of agricultural credit. From 1993 to 1997, real growth in the agricultural sector averaged 5.7% but has since declined to about 4%. Agricultural reforms, including increased wheat and oilseed production, play a central role in the government's economic reform package. Outdated irrigation practices have led to inefficient water usage in Pakistan. Twenty five per cent of the water withdrawn for use in the agricultural sector is lost through leakages and line losses in the canals.

Only a limited amount of the remaining water is actually absorbed and used by the crops due to poor soil texture and unlevelled fields. Much of the Pakistan's agriculture output is utilized by the country's growing processed food industry. The value of processed retail food sales has grown 12 percent annually during the nineties and was estimated at over $1 billion in 2000, although supermarkets accounted for just over 10% of the outlets. The Federal Bureau of Statistics provisionally valued major crop yields at Rs. 504, 868 million in 2005 thus registering over 55% growth since 2000 while minor crop yields were valued at Rs.184707 million in 2005 thus registering over 41% growth since 2000. The exports related to the agriculture sector in 2009-10 are Rs 288.18 billion including food grains, vegetables, fruits, tobacco, fisheries products, spices and livestock.[23]

## Current Research Proceedings in Pakistan on Biofertilizer

Research proceedings in Pakistan are making a slow but steady progress. Research is going on in the fields of use of Azolla sp. mixed with chemical.[14] N labeled ammonium sulfate was used for checking nitrogen recovery in rice fields and it was found to be beneficial for increased rice biomass, uptake of N fertilizer and increased recovery rate of the same.[24] A study was conducted to investigate the effect of biofertilizer on wheat variety Zardana production at four locations of Baluchistan. Biofertilizer (Azospirillum A1-Q+N 45 $kgha^{-1}$, PO 30 kg $ha^{-1}$) was used to substitute for half of the Nitrogen (N) and Phosphorus (P) fertilizer application rates as compared to a high fertilizer treatment (N 90 $kgha^{-1}$, $PO_2$ 560 $kgha^{-1}$). The high mineral fertilizer and biofertilizer + half mineral fertilizer treatments were compared with a control treatment (no fertilizer). Significant grain yield were measured at all sites, although, at all sites both fertilizer treatments apparently out yielded the control and the biofertilizer + half mineral fertilizer treatment out yielded the high fertilizer treatment by 220- 1180 $kgha^{-1}$. Fresh yields differed significantly at all sites. At Mastung field, both fertilizer treatments out yielded the control by 3000 $kgha^{-1}$ and at Quetta (Aghbarg field-2) the biofertilizer + half mineral fertilizer treatment out yielded the others by over 3000 $kgha^{-1.}$ The results proved that the application of biofertilizer in combination with N 45$kgha^{-1}$ and $PO_4$ 30 $kgha^{-1}$ increased the fresh yield from 11% to 59% and suggested increases in grain yield of 20-46% as compared to control treatment.[24]

## Government Policies

Since deregulation, urea prices have followed an upward trend. Several factors have contributed to the price hike. Some of the important factors are the general inflationary trend, increase in the price of gas particularly used as fuel and upward adjustment in the cost of production due to increase in salary and wages. Government imposed 15 per cent General Sales Tax (GST) on urea in February 2001, which resulted in an increase of about Rs. 50/bag. The country has achieved self-sufficiency in urea, but may have gone in imports by years 2004-05. Prices in international market are volatile and any imports in coming years will result in further price hike. Government is providing indirect subsidy on gas to fertilizer producers at around $0.2 billion/year. There has been contention that this subsidy is not being passed on to farmers, whereas industry's view point is that while comparing with international prices subsidy is passed on to farmers. It was speculated that a new fertilizer plant of urea may be required by year 2005-06. Efficient marketing and distribution arrangements are essential for improving the efficiency of both fertilizer use and supply. It is through marketing channels that fertilizer reaches the farmers on time, in the right quantity and quality, and at the right price. The complaints of under- weight bags and poor quality of the products of the new importers are frequent. The mal practices in fertilizer marketing and distribution such as fake, adulterated and underweight are frequently reported by farmers. Provinces of Punjab and Sindh have implemented 'Fertilizer Control Acts' to ensure quality at retail level. However, 'Fertilizer Legislation' is pending for approval and implementation under Federal Government to regulate quality of imported fertilizers. The fertilizer research particularly in the provinces should address the issues of efficiency, proper rates and should minimize losses to protect environment. Extension activities in the provinces are not up to mark due to a variety of factors. Provincial agricultural extension should be properly trained to disseminate information on fertilizer use to the farmers. The Government of Pakistan in early 1960s started agricultural credit scheme through Agricultural Development Bank of Pakistan (ADBP), renamed as Zarai Taraqiati Bank Limited (ZTBL). Recently, the Commercial Banks and Domestic Private Banks have also started disbursing agriculture credit to the farming community. Credit is provided to farmers for purchase of seeds, fertilizers, and pesticides as well as for purchase of agricultural machinery. Government policy with regard to agricultural credit is to safeguard the interest of small/medium farmers by extending credit to them on easy terms and recovering the same in time as well as to protect them in case of any natural hazards and calamity. Ministry of Food, Agriculture and Livestock plays an active role in monitoring agricultural credit disbursement and conducts meetings to remove the bottleneck/hurdles in disbursement. Present regime gives special emphasis to resolve the credit problems of farming community. Agriculture credit is provided for production and development purposes. Production loan is being provided for agriculture input comprising of seeds, fertilizer, pesticides/ insecticides, poultry/animal feeds, chicks medicines and water charges, electric charges for tubewells, labor, fuel and ice of marine fisheries. The development loan is provided for agriculture machinery i.e. purchase of tractors, installation of tube wells, pumping set, reapers, cutter binders, threshers, trolley, spray machinery and cane crusher.

## Current Facilities to the Farmers in Pakistan

Farmers are being financed from the banks on the basis of multiple/ revolving limits for a period of three years in addition to demand finance in single disbursement. Revolving limits can be availed not only against 100% adjustment/ repayment of previous loan but also in case of partial adjustment/ repayment without any fresh documentation. Lease financing facility against pledging of tubewells and tractors with the banks is provided if these are free from all encumbrances. Finance for Agricultural produce by farmers/ marketing companies against raw cotton, cotton yarn, mutton and beef, wool and animal hair, food stuff for animals is provided. Non-fund based facilities (LCs and Guarantees) can be opened/ availed by the Corporate Farming. In addition to commercial banks, agricultural credit facility can also be availed by the micro credit institution, recognized NGOs and Rural Support Organization for onward lending to farmers/ growers/ borrowers. For meeting the liquidity shortfall, the farmers/ growers/ borrowers can avail discount on deferred payment vouchers issued by the tobacco, sugarcane and other processing units from the commercial banks. Agriculture finance against mortgage of Defense Saving Certificates (DSCs), Special Saving Certificates (SSCs), gold and silver ornaments is provided. In order to redress the problems of farmers at their doorstep, State Bank of Pakistan (SBP) has established Credit Advisory Committees and Sub-Committee at its 15 SBP Offices (Karachi, Lahore, Quetta, Peshawar, Islamabad, Rawalpindi, Multan, Faisalabad, Sialkot, Bahawalpur, Gujranwala, D.I.Khan, Muzaffarabad, Hyderabad and Sukkur). A farm loan help Desk is functioning in the Agriculture Credit Department, State Bank of Pakistan, Karachi to facilitate the farmers/borrowers.[25]

## Manufacturers/ Suppliers of Biofertilizer in Pakistan

**Table 9.Few biofertilizer manufacturers and suppliers of biofertilizer in Pakistan[26]**

| Name of companies | Products |
|---|---|
| Achen Enterprises | Liquid biofertilizer |
| Karishma Fertilizer | Organic biofertilizer |
| AMB Organics | Organic biofertilizer |
| NK Agro Chemicals | Organic biofertilizer |
| Bio Green | Granularbiofertilizer, Compost, organic and liquid biofertilizer |

## Sri Lanka

Agriculture holds utmost importance for economy in the country as apart from agriculture, travel and tourism, no others sector is much developed in the country, especially the services sector, which generates maximum revenue as well as maximum employment in any country. Rice is the single most important crop occupying 34 percent (0.77 /million ha) of the total cultivated area in Sri Lanka. On average 560,000 ha are cultivated during summer and 310,000 ha during winter making the average annual extent sown with rice to about 870,000 ha. About 1.8 million farm families are engaged in paddy cultivation island-wide. Sri Lanka currently produces 2.7 million tonnes of rough rice annually and satisfies around 95 percent of the domestic requirement. Rice provides 45% total calorie and 40% total protein requirement of an average Sri Lankan. The per capita consumption of rice fluctuates around 100 kg per year depending on the price of rice, bread and wheat flour. It is projected that the demand for rice will increase at 1.1% per year and to meet this, the rice production should grow at the rate of 2.9% per year. Increasing the cropping intensity and national average yield are the options available to achieve this production targets. The current cost of production of rough rice is Rs. 8.57 per kg. The cost of labor, farm power and tradable inputs constitutes 55%, 23% and 23% respectively. The labor cost has risen at a higher rate than other costs over the last few years. While the global demand for rice will increase at 1.95%, the production will increase at 1.62% per annum making the tradable rice volume to be doubled in another 20 years time. As a result, the rice price would decline at 0.73% per year. On the other hand, the domestic price of rice on par with Thai A1 super (the cheapest in the world market) would be higher by 50-70 USD per t than the internationally traded rice. This situation will place Sri Lanka under increased pressure to produce cheaper and high quality rice in the coming years. Tea industry was introduced in the country in 1847 by James Taylor, the British planter who arrived in 1852. It is one of the main sources of foreign exchange for Sri Lanka and accounts for 2% of GDP, generating roughly $700 million annually for the economy of Sri Lanka. It employs, directly or indirectly over 1 million people, and in 1995, 215,338 people directly employed on tea plantations and estates. Sri Lanka is the world's fourth largest producer of tea. In 1995, it was the world's leading exporter of tea, (rather than producer) with 23% of the total world export, but it has since been surpassed by Kenya. The humidity, cool temperatures, and rainfall in the country's central highlands provide a climate that favors the production of high quality tea. The major tea growing areas are Kandy and Nuwara Eliya in Central Province, Badulla, Bandarawela and Haputale in

Uva Province, Galle, Matara and Mulkirigala in Southern Province, and Ratnapura and Kegalle in Sabaragamuwa Province.

A small step has been taken by the Sri Lankan government for making an Agro Technology Park which is one of the finest initiatives for agriculture extension, education and agro tourism implemented by the Department of Agriculture, Sri Lanka. The first A-Park was established in Kandy district. The park is bounded on three sides by the river Mahaweli in the historically important place of Gannoruwa in Kandy and, lies at an altitude of 473 m (1550 ft) above sea level in a total area of 2 square kilometers. It contains majority of the institutions of the Department of Agriculture. The second A-Park was established in Hambantota district adjoining to the Government Farm in Batatha.[27]

## Research and Development of Bio Filmed Biofertilizers in Sri Lanka

The research on biofertilizer in Sri Lanka has made a breakthrough and is called biofilmed biofertilizer. The research proceedings are discussed below in a nutshell. Maize is cultivated as a second crop next to rice in tropical conditions and depends on Chemical Fertilizers (CF) which contribute to detrimental ecological consequences. As a recent development, Formulated Fungal-Bacterial Biofilms (FBBs) of nitrogen fixing bacteria and fungi have shown potentials to be used as biofertilizers in agriculture, and are Biofilmed Biofertilizers (BFBFs). Therefore, current study was focused on the effect of developed BFBFs on plant growth and soil nutrient availability under CF reduction. A greenhouse soil pot experiment was conducted for 60 days using treatments; 100% CF (Recommended dose by the Department of Agriculture), 50% CF, 50% CF + BFBF1 and 50% CF + BFBF2, two BFBFs formulations. Plant photosynthetic efficiency and total plant dry weight were measured after 45 and 60 days of plant growth, respectively, and soil available ammonium ($NH_4^+$), nitrate ($NO_3^-$), phosphate ($PO_4^{3-}$) and soil organic carbon (SOC) were measured following standard methods at 60 days of plant growth. Initial availabilities of $NH_4^+$, $NO_3^-$, and $PO_4^{3-}$ were 42.76, 15.08, and 2.41 μg/g soil, respectively. Results showed that 50% reduction of CF did not affect plant growth, since nutrient use efficiency was presumably improved by the BFBF. Enhanced plant photosynthetic efficiency under BFBF application was possibly due to sufficient chlorophyll content in plant leaves, caused by adequate supply of $NH_4^+$. In contrast, reduced availability of $PO_4^{3-}$ (0.24 μg/g soil) under BFBF2 could be due to plant uptake, possibly through the enhanced root growth. Thus, BFBF can reduce CF input in maize agriculture for a sustainable system. Further experiments under field conditions are however needed to evaluate their potential use in maize cultivation.[28]

## Methods to Improve Food Security with Worthy Sustainable Alternatives

The Central Bank of Sri Lanka (1987) defined poverty as the lack of income to buy the basic minimum of food caloric energy. According to the Central Bank of Sri Lanka, a fifth of all households do not consume the required minimum in caloric food energy. Possible reasons for the above inadequate energy provision are associated with numerous technological, socioeconomic and political factors. Food security is important for healthy and peaceful development and depends on both the demand and the supply of food. The gap between the demand and supply of certain commodities including wheat flour, chillies, dhal and onions is bridged by imports. The extent of imports is correlated with the production of respective commodities. There is a wide range of factors that affect the food demand and the supply. Among them, population growth and distribution, income changes due to socio-economic factors, urbanization and industrialization, agro technology employment, acceptance of local foods at the market, unsecured income of farmers, change of life styles due to open economy, ecological and environmental problems related to food production, lack of long term national planning and Government policies towards the prevention of looming famine, gender inequity in agricultural and food technological activities and food losses due to improper post- harvest handling are of significance. Accordingly, the following can facilitate improved food security.

- Improvement of agro technology
- Plant breeding programs for improved varieties
- Optimal use of lands which are under unfavorable stress conditions
- Popularization of use of alternative crops as substitutes for major food commodities
- Long term government policies and their efficient implementation mechanisms
- Promotion of extension programs
- Development and improvement of postharvest handling systems, processing and method of storage at all levels[29]

## Conclusion

The necessity for a potential worthy alternative to chemical fertilizer is an existing entity in the form of biofertilizers which is a very feasible option when it comes to reduction of agro-chemical inputs in agriculture. It may help in providing food security to the entire population of countries like Pakistan and Sri Lanka who depend a lot on imports when it comes to crops like wheat, chili in case of Sri Lanka and combating drought which often takes place in northern parts of Pakistan. In riverine countries like India, China and Bangladesh, agriculture can become a potentially huge industry boosting the generation of revenue at par with the services sector and thereby helping in all round development of the economy. Iran is dynamic when it comes to economy but it heavily depends on crude oil and gas exports for generation of revenue and given the current world crisis indigenous agro-research may help Iran in sustaining themselves. The gap between R&D and Industry is quite visible from the above study where the research has not been taken into practice on the principle of 'market pull- technology push'. The manufacturing units of all the countries are very conventional when it comes to fertilizer products mainly consisting of compost products and some liquid organic fertilizers.

Some specific policies of the government should be altered in an immediate effect so as repair the already done damage by chemical fertilizers on the soil ecology in different agrarian regions of this country. There should be proper initiatives at the grass root level to make people aware in using biofertilizers and their applications, training them in post-harvest soil handling techniques, improving technology to make soil ecology sustain a multi crop harvest all round the year. The effective result would only be possible if governments of countries also help agriculturists in consolidating money both for research and application with proper investment security so that a certain individual gets value for money on practicing these methods. Lastly, the south Asian countries have developed in many sectors of the economy but overlooking or neglecting a sector such as agriculture may be a cause of serious concern in the future.

**Conflict of Interest:** None

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