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REVIEW ARTICLE

Role of Biofertilizers in Rajasthan Sustainable Agriculture

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Abstract

Soil fertility and human health has been hampered greatly due to the excessive use of chemical fertilizers in crop yield to meet the increasing demand of crop production. Use of biofertilizers is encouraging sustainable agriculture, an alternative and environment-friendly perspective in contrast with chemical fertilizers. The leading example of environment-friendly biofertilizers are Plant Growth-Promoting Microorganisms (PGPM). Enhancement in growth and overall development of the crop plants have been observed with the close association of many bacteria and fungi with the plant. Agricultural industries have been formulating strategies for optimizing bio formulations. Thus understanding the mechanism of these microorganisms can help us to manipulate and produce microbes to be used as biofertilizers. Modification of a microbe into a biofertilizer, distinguishing properties of microorganisms and an approach to optimize bio-formulations have been discussed in this review article. An effort has been made to understand different application methods of biofertilizers and a practical approach of potential role of biofertilizers used for crops grown in Rajasthan.

Keywords: Biofertilizers, Fertilizers, Microorganisms, Plant growth-promoting microorganisms.

Introduction

Increase in human population has led to escalated food demands and agriculture has played a vital role in meeting these demands. To meet this demand, usage of chemical fertilizers and pesticides has increased remarkably. Chemical fertilizers and pesticides consist mostly of Potassium, Phosphorus and Nitrogen but exploitation of chemical fertilizer cause air, ground and water pollution by eutrophication of water bodies (Bhardwaj *et al.*, 2014). Indiscriminate use of chemical pesticides has contributed in decline of soil productivity along with addition of salts to the soil (Aggani, 2013).

To ensure bio-safety more efforts have been focused towards the fabrication of 'nutrient rich high quality food' (Bhardwaj *et al.*, 2014). All the microorganisms responsible for adding essential nutrients or making them available to the plants are known as biofertilizers. In contrast, biofertilizers and chemical fertilizers differ from each other extensively as prior are known to be the latent or living form of microorganisms and later are manufactured within the factories (Pathak and Kumar, 2016). The term biofertilizer incorporate selective microorganism like bacteria, fungi and algae. The biofertilizer with nitrogen fixer & phosphate solubilizer fixes about 20-40 Kg of nitrogen per acre (Aggani, 2013). Biofertilizers are nutrient availability systems to harvest the naturally available nutrients in which biological process are involved (Aggani, 2013). It plays an important role in reviving the soil health either by mobilizing different elements present in the soil or by adding nutrients from the environment. Additionally, living on substitute source has become imperative idea of biofertilizers, which can be a good enhancement for chemical fertilizers.

Despite the fact that the utilization of chemical fertilizers in farming is inescapable to fulfil the expanding need of food across the world, there are noticeable opportunities in certain crops and niche areas where organic production can be empowered. One such area with the increasing popularity of biofertilizer is Rajasthan. Agricultural society being a significant part of the economy of Rajasthan accounts for about 22.5% of the agricultural sector (Ghosh, 2011). The lack of sufficient annual rainfall makes a major part of the state parched and infertile and hence, agricultural practices become difficult. In such situations biofertilizers tend to play a major role by making more plant nutrients available to the plants through natural processes such as nitrogen fixation, solubilizing phosphorus, etc. However, not much studies have been done on the role of biofertilizers in Rajasthan's sustainable agriculture. By the virtue of this article, we have tried to explore the Rajasthan's agricultural system, scenarios where biofertilizers have been used to enhance the crop yield and the difficulties faced with field application of biofertilizers for these crops along with their possible

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solutions. The major crop season of Rajasthan are Rabi and Kharif and based on the crops grown, different types biofertilizers are being used which has been discussed below.

Types of Biofertilizers and their Mechanism

Interaction amongst organisms and their environment is essential for their functioning and survival in the ecosystem. For a better habitat, organisms support each other to acclimatize to a particular situation. Favourable bacteria and mycorrhiza contribute to the functioning of plants cellular organization and thrive in close proximity with them. Most common microorganism found in the root nodules of leguminous plants is *Rhizobium* and only after its symbiosis with the host plant, its mechanism of nitrogen fixation can be operated. In turn, *Rhizobium* also helps in bringing several changes in the plants habitat (Hasanuzzaman *et al.*, 2013). Bio formulations can be classified into three extensive groups (Table 1) i.e. plant growth-promoting microbes (PGPM), phosphate solubilizers and nitrogen fixers in accordance with their microbial functional traits.

Nitrogen Fixers

Nitrogen-fixing microorganisms are responsible for conversion of atmospheric dinitrogen into ammonia by biological nitrogen fixation (BNF) which is an ATP-driven process (Gothwal *et al.*, 2008). It is recommended to use specific bioformulation for a plant, as certain plant groups can only be colonized by specific nitrogen fixers (Table 2). Nitrogen-fixing microorganisms are free-living, associative or symbiotic in nature (Mazid and Khan 2014). Example for bioformulation includes like, *Azospirillum* (a free-living nitrogen fixer), for C4 plants specially, as it requires salt of organic acids like aspartic and malic acid for nitrogen fixation. Similarly, *Rhizobium* nitrogen fixer is appropriate for leguminous plants (Mazid and Khan 2014).

Rhizobium

Rhizobium belongs to family Rhizobiaceae. They can be found living in symbiosis with legumes in nature. *Rhizobium* can fix nitrogen up to 50-100 kg/ha with legumes only. For a particular legume, the availability of compatible strain of *Rhizobium*, for the successful

Table 1. Different groups of microorganisms used in Bioformulation (Suhag, 2016)

Groups	Examples
Nitrogen fixing biofertilizers	
Symbiotic	*Rhizobium, Anabaena azollae* and *Frankia*
Free living	*Azotobacter, Clostridium, Nostoc, Beijerinka, Klebsiella,* and *Anabaena*
Associative symbiotic	*Azospirillum*
Phosphate mobilizing biofertilizers	
Ectomycorrhiza	*Pisolithus* sp., *Laccaria* sp., *Amanita* sp. and *Boletus* sp.
Arbuscular mycorrhiza	*Gigaspora* sp., *Acaulospora* sp., *Glomus* sp., *Sclerocystic* sp. and *Scutellospora* sp.
Orchid mycorrhiza	*Rhizoctonia solani*
Ericoid mycorrhiza	*Pezizella ericae*
Phosphate solubilising biofertilizers	
Fungi	*Penicillium* sp. and *Aspergillus awamori*
Bacteria	*Bacillus subtilis, Bacillus megateium, Phosphaticum, Pseudomonas striata* and *B. circulans*
Plant growth promoting rhizobacteria	
Pseudomonas	*Pseudomonas fluorescens*
Biofertilizers for micro nutrients	
Silicate and Zinc solubilizers	*Bacillus* sp.

nodulation of leguminous crops plays an important role. Root nodules are formed when *Rhizobium* colonizes the roots of specific legumes, which acts as factories of ammonia production. It has been observed that in absence of legumes, the population of *Rhizobium* decreases. To hasten the process of N-fixation, and to restore the population, effective *Rhizobium* strains by artificial seed inoculation method is often used near the rhizosphere. It is of utmost importance to match microsymbionts prudently for N-fixation to occur effectively (Poonia, 2011).

Azospirillum

It belongs to the family of Spirilaceae. *Azospirillum* is heterotrophic, associative, additionally producing growth regulating substances which can promote plants growth and can fix 20-40 kg/ha area. The most common genera being *A. lipoferum* and *A. brasilense* (Mishra *et al.*, 2013). As *Azospirillum* can grow and fix nitrogen on salts of organic acids such as aspartate and malic acid, they form symbiotic association with plants showing Hatch and Slack pathway of photosynthesis.

Azotobacter

Azotobacter , family Azotobacteriaceae, are heterotrophic, free living, aerobic, found in neutral or alkaline soils, *A. chroococcum* found in arable soils is the most common (Sethi and Adhikary, 2012). The number of *Azotobacter* rarely exceed from 104 to 105 g^{-1} of soil due to antagonistic microorganisms in soil and the scarcity of organic matter. This can be overcome with the help of the bacterium producing anti-fungal antibiotics which prevents seedling mortality by inhibiting the growth of pathogenic fungi in the root region (Sethi and Adhikary, 2012). Under in vitro conditions the isolated culture of *Azotobacter* is capable of fixing about 10 mg N g^{-1} of carbon source. Biologically active growth promoting hormones such as Indole acetic acid (IAA), vitamins of B-group and gibberellins are known to be synthesised by *Azotobacter* (Mishra *et al.*, 2013).

Cyanobacteria* and *Azolla

Cyanobacteria and *Azolla* are also known as paddy organisms as they are abundant in paddy and are responsible for producing IAA, Gibberllic acid and Auxins. *Cyanobacteria* and *Azolla* are phototrophic in nature and can fix about 20-30 kg Nitrogen per ha in areas of submerged rice fields (Chatterjee *et al.*, 2017). Soil nitrogen and BNF are the significant sources of nitrogen for low rice production, also N is the key ingredient required in large quantity by the soil. With the help of this combination requirement of 50-60% of N is met by free living and rice plant associated bacteria (Mishra *et al.*, 2013). Filamentous bacteria, consist of specialized cells known as heterocyst, function as micro nodule for synthesising and fixing nitrogen in the soil which are characteristics feature of most N fixing *Blue Green Algae (BGA)*. *BGA* is known to form symbiotic association with fungi, liverworts, ferns and flowering plants, capable of fixing nitrogen, yet the best of association is with free floating aquatic fern, i.e., the *Azolla* and *Anabaena azollae*. *Azolla* contains 0.2-0.4% of N on wet basis and 4-5% of N on dry basis, hence it can be considered as a potential source of nitrogen and organic manure in rice production, also its ability of quick decomposition in the soil makes it an essential biofertilizer. Besides Nitrogen fixation, these biomanures also contribute a significant amount of macronutrients such as Phosphorus, Potassium, Sulphur, Zinc, Iron, Molybdenum and other micronutrient (Yao *et al.*, 2018).

Table 2. Nitrogen fixer biofertilizers and crops suited (Bhat *et al.*, 2015)

Name	Crops suited
Rhizobium	Pulse legumes examples red-gram, pea, chickpea, lentil, black gram, etc., Oil-seed legumes examples groundnut, soybean, forage legumes examples Lucerne and Berseem.
Azospirillum	Sugarcane, Sorghum, Maize, Pearl millet etc.
Azotobacter	Rice, Sugarcane, Bajra, Maize, vegetables and plantation crops.
Cyanobacteria and Azolla	Rice

Phosphate Solubilizers

Phosphate solubilizing microbes are another important group of microbial biofertilizer which benefits the plants by solubilizing bound phosphorus from inorganic or organic complexes, thus making it easily available for plant uptake Gluconic and Citric acids having low molecular weight, are produced by soil bacteria possessing carboxyl and hydroxyl groups and can form bonds with the cations such as Ca, Al, Fe bound to insoluble phosphatic compounds which in turn, releases the soluble phosphorus for plant uptake. It has been observed that both solubilisation and mineralization activities can be carried out by some microbes (Pereira and Castro, 2014) manifesting phosphate solubilizers as incredibly effective biofertilizing agent. In contrast with non rhizosphere soil, a noticeably high concentration of plant solubilizing bacteria is locally present in the rhizosphere soil (Raghu and Macrae, 2000).

Plant growth-promoting microbes (PGPM)

Pseudomonas spp. are the most common examples of plant growth promoting rhizobacteria. By producing hormones and anti-metabolites *Pseudomonas* contribute majorly in increasing the availability of nutrients which enhances root growth, improve crop yield and help in mineralization of soil by decomposing organic matter.

PGPM are also referred as crop specific biofertilizers like *Rhizobium*. The five major areas by which Plant growth promoting rhizobacteria enhances the nutrient availability of host plants can be categorized as following: (1) dinitrogen fixation, (2) increasing the availability of nutrients in the rhizosphere, (3) improving other beneficial interactions of the host (4) increase in root surface area, and (5) combination of different mechanisms (Ramasamy *et al.*, 2020)

Bio fertilizers in Rajasthan

Rajasthan is the largest state in India, located in the north-western part, with an area of about 342,239 sq. km. It covers about 10.5% of the total geographical area of the nation while only 1% water is available in the state (Singh and Kumar, 2016). But, because of the diverse agro-climatic conditions, Rajasthan's grows varied crops and agriculture sector alone contribute 25.56% of state's total Gross State Domestic Product (Hussain, 2015). Rajasthan is a known producer of Onion, Maize, Moong, Bajra, Wheat, Guava, etc. One of the major contributing factors to this increasing cultivation is the use of biofertilizers (Table 3).

Major Breakthrough in Rajasthan

The government of Rajasthan lays emphasis on use of biofertilizers in view of soil and human health and environmental protection. Several schemes are in vogue in the state for the promotion of usage of biofertilizers for sustainable agriculture:

- Paramparagat Krishi Vikas Yojana (PKVY)
- Rashtriya Krishi Vikas Yojana (RKVY)
- National Horticulture Mission (NHM)
- Rainfed Area Development Programme (RADP)

Rajasthan Kisan Aayog has also taken initiatives for promotion of use of biofertilizers and sustainable agriculture for the farmers of Rajasthan.

Relevant Case Studies

Case Study I: Increase in production and quality of wheat crops in Rajasthan by using biofertilizer inoculation has been verified, tested and estimated.

Wheat (*Triticum aestivum L.*) is an important staple crop worldwide. Wheat ranks first among the cereal crops in case of increasing demands. It is still a challenge in many countries to increase the production of wheat to meet the higher demands (Ram *et al.*, 2014). In such scenario, attempts has been made in Rajasthan to increase the production and quality of *Triticum aestivum L.* Use of plant nutrients in balanced and sufficient amounts along with maintaining the soil fertility in sandy soil is one of the key factor in increasing crop yield. As Nitrogen is the most important nutrient required by the non-legume crops, including wheat, nitrogen fixer biofertilizers such as *Azotobacter sp.* and *Azospirillum sp.* can be used. Adequate supply of nitrogen is necessary in achieving high yield of wheat as nitrogen influences the cell size, photosynthetic activity, number of grains spikes, length of spikes, etc.

Table 3. Major crops grown in Rajasthan and Biofertilizers used

Biofertilizer	Example	Targeted crop	References
Rhizobium	*Mesorhizobium, Bradyrhizobium, Azorhizobium*, etc.	Leguminous crops	Poonia, 2011
Azotobacter	*Azotobacter chroococcum*	Cereals, Millets, Vegetables and other horticultural crops	Sumbul *et al.*, 2020
Azospirillum	*Azospirillum brasilense*	Maize, Bajra, Potato, etc.	Dommelen and Vanderleyden, 2007
Acetobacter	*Acetobacter diazotrophi cus*	Sugarcane and Sugarbeet	Manimaran *et al.*, 2009
Phosphorus solubilizing bacteria	*Pantoea agglomerans; Penicillium* and *Asperg illus*	For all the crops	Kalayu, 2019
Trichoderma viride Biofungicides	*Trichoderma viride*	For all the crops	Mahato *et al.*, 2018

(Table 4). The contribution of these free-living nitrogen fixers to the nitrogen input of soil ranges from 0-60 kg/ha to 160 kg/ha (Mukhtar *et al.*, 2017).

Table 4. Effect of biofertilizer inoculation on wheat yield (Mukhtar *et al.*, 2017)

Factors	Increased by
Plant height	20%, the highest plant height observed was from 100 cm to 120 cm.
Number of spikes (M^{-2})	600 to 650 spikes
Number of grains per spikes	45 to 52 grains/spike
Grain weight	42 to 50 g
Biological yield	10%

The results obtained from this case study indicate that the wheat yield and protein contents of grains have an association with biofertilizer. Increased use of biofertilizer inoculations increased number of spikes, grain weight, plant height, etc.

Case study II: Effect of biofertilizer on productivity of Groundnut (*Arachis hypogaea L.*) in arid region of Rajasthan.

Groundnut is the prime oil seed crop in India. The soil of the arid region of Rajasthan has loamy sand, is low in organic carbon, and have low number of available nitrogen, phosphorus and potassium which can be enhanced with the use biofertilizers (Table 5) (Ola *et al.*, 2013). Hence, a combination of *Rhizobium* and Phosphorus solubilizing bacteria can be used as biofertilizer for increasing the productivity of *Arachis hypogaea L.*

Table 5. Effect of biofertilizer inoculation on Groundnut (Ola *et al.*, 2013)

Factors	Increased by
Number of branches per harvest	7.23 to 7.43 in number
Number of pods	31.86 to 33.04 in number
Pod yield (kg/ha)	146 to 247 kg/ha
Oil content (%)	5%
Oil yield (kg/ha)	117 to 9,779 kg/ha

Inoculating seed with symbiotic nitrogen fixers increases the number of healthy and efficient nodules of *Rhizobium* which results in increased fixation of atmospheric nitrogen in the soil being used up by the plants and hence, results into higher growth. Phosphorus solubilizing bacteria increases the availability of phosphorus which helps in enhanced uptake of essential nutrients that helps in improving the yield attributes and finally the pod yield. Also, increased oil content of seed was observed after the inoculation of phosphorus solubilizing bacteria.

Case study III: Effect of biofertilizer on enhanced yield of Garlic (*Allium sativum L.*) in Rajasthan

Garlic is the second most cultivated after onion. The major garlic producing states are Karnataka, Rajasthan, Gujarat, Orissa and M.P. The soil in which garlic is cultivated is slightly alkaline in nature, sandy loam and low in sodium content. Hence, Vesicular-Arbuscular Mycorrhiza (VAM) can be used as a biofertilizer inoculant for increased production (Table 6). VAM have extensive mycelial network and increases the transport of minerals including phosphorus to plants. It can enhance the phosphorus intake by 25-30% (Kumar and Singh, 2020).

Table 6. Effect of biofertilizer inoculation on Garlic (Kumar and Singh, 2020)

Factors	Increased from
Plant height	41.56 to 63.29 cm
Length of leaves	38.56 to 45.16 cm
Number of cloves per bulb	20.527 to 27.420
Length of cloves	3.120 to 4.980 cm
Bulb yield	64.630 78.727 Q/ha

From the above listed results it can be concluded that VAM biofertilizer plays an important role in increasing the yield and quality of Garlic.

Biofertilizer Application Methods

There are three ways in which biofertilizers can be applied

Seed Inoculation or Seed Treatment

Seed treatment is the key application method used for different kinds of bio inoculants, here, the inoculant in the form of slurry is mixed with seeds (Renjith *et al*., 2020) and then mixture is shaken continuously so that biofertilizer forms a uniform layer onto each seed. The seeds being inoculated are shade-dried for 20 to 30 min. and sown immediately. It is one the most effective and economical application method. In fact inoculants of *Azotobacter, Rhizobium, Azospirillium* and phosphate solubilizing bacteria are applied through seed treatment. For an acre of land 150-200 g of inoculant is sufficient to treat seeds (Prabhudesai, 1999).

Main Field Application or Soil Application

The second application method is the direct soil application which is carried out by the broadcasting method of biofertilizer application on plantation or before sowing. Soil application is mostly practiced for field crops where localized application is needed such as plantation crops, fruit crops, for sugarcane, etc. Depending on the plant's density, 2-4 kg of the recommended biofertilizer is mixed with 50-100 kg of compost for one acre of land (Prabhudesai, 1999) .

Tuber/ Root/ Seedling Inoculation

This method is majorly used for cut pieces of potato, seed-sets of sugarcane and forest nurseries. For application on seedlings, the required seedlings should be inoculated using 2-2.5 kg of biofertilizer for one acre of land (Prabhudesai, 1999). It has been found most effective for crops like onion, tomato, flowers, etc.

Problems Associated with Field Applications of Biofertilizers and their Probable Solution

A considerable increase in use of biofertilizers have been seen amongst the farmers lately, because of the well-known negative effect of chemical fertilizers. However, the biofertilizer industries have not grown much because of the under-developed biofertilizer markets (Herrmann and Lesueur, 2013) Also, some problems and constraints have been reported by the farmers when it comes to the field application of biofertilizers (Table 7). If the roots of these problems can be identified and possible solutions can be formulated, then the use of biofertilizers can be increased.

Potential role of biofertilizers in farming: a practical approach

Strength

A modern approach of disease management i.e., Bio-control can be a significant role of biofertilizer in organic farming. The most concerned disease of root rot of mung bean has been found to control by a bio based fungicide, *Trichoderma.* (Ritika and Uptal, 2014). With the use of biofertilizers containing microbial strains of specific bacteria, nitrogen fixers, phosphate and potassium solubilizers, yield and quality parameters of certain crop plants can be enhanced (Khosro and Yousef, 2012). Some of the important characteristic features of biofertilizers that needs to be highlighted are: They helps in the secretion of plant growth hormones which in turn helps in the plant growth, protect plants under the attack of pathogens, improves soil fertility, accelerating use of biofertilizers have decreased use of fertilizers significantly. Also, Biofertilizers are less costly as compared to chemical fertilizers, they helps to restore and enhance the soils natural nutrient cycle and most importantly provides protection against drought (Itelima *et al.*, 2018). Using biofertilizers in dry land can be benefitted by applying one or other type of biofertilisers. Likewise, high quality of biofertilizers offer wide potential in North Eastern Hill

Table 7. Difficulties faced by the farmers and their possible solutions (Parmar *et al.*, 2017)

S.no	Difficulties	Probable Solutions
1.	Lack of technical skill to use biofertilizers	Training should be provided about the use of bio-fertilizers to the farmers
2.	Lack of technical knowledge about bio-fertilizers	Provide information about the benefits of biofertilizer
3.	Non-availability of good quality bio-fertilizers	Quality bio-fertilizers should be made available
4.	Non-availability of bio-fertilizers from all dealers	Sound marketing network for biofertilizer should be established
5.	Lack of storage facility for biofertilizer	Successful bio-fertilizer farms and farmers be identified and designated for farmers training and cold storage facilities should be build
6.	Lack of awareness about the benefits of bio-fertilizers	Farmers should be aware that they can get better yield by the use of biofertilizers
7.	No visual difference in crop growth immediately as compare to chemical biofertilizers	Awareness campaign on popularization of bio-fertilizers should be organized and trust of farmers should be gained
8.	Lack of guidance from extension personal	Extension field functionaries should be trained in biofertilizer aspects
9.	Poor self-life of bio- fertilizers	Research on use of biofertilizer should be taken urgently
10.	Lack of finance.	Banks should provide loans at low interest rate and efforts should be made to lower the formulation cost of biofertilizers.

Table 8. Market revenue of biofertilizers worldwide (Cision, 2019).

Biofertilizers	Year										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Nitrogen fixing (USD Million)	50	55	75	88	104	120	140	145	150	180	210
Phosphate solubilizing (USD Million)	10	10	13	22	26	40	30	30	55	60	62
Others (USD Million)	10	10	12	20	25	35	30	35	50	55	60

Zones (Venkateswarlu, 2008). Through various schemes of Government of India like National Project on Sustainable Farming, Rashtriya Krishi Vikash Yojana, National Horticultural Mission, technical and financial assistance are being provided to promote biofertilisers in agriculture.

Limitations

Some inevitable challenges in respect with biofertilizer use- As biofertilizer is a living or latent form of microbe unfortunately it doesn't have an adequate shelf-life and can't be used after mentioned expiry date. Poor storage facilities can lead to decline in the number of viable cells of the microorganisms and in turn might become ineffective. Occasionally the quality of the product gets substandard which in turn discourages the farmer's for its use, also, method of applications can sometimes be time consuming (Bhattacharyya, 2014). Because of specific limitations which incorporate variable like biotic and abiotic factors, high expectation on enhancing crop productivity can be a major threat as it isn't generally possible to keep up. Rise of some Bio-Organic mafia bunches lately, selling substandard products is a significant issue. It is highly unlikely to check whether genetically modified organisms are really utilized as source of strains during manufacturing of the item or not.

Commercialization of Bio fertilizer and Patents Filed

Across the years the maximum change in the composition of biofertilizer was found in the year 2010-2011 (Barman *et al.*, 2017). The maximum production capacity of biofertilizer can be seen in Agro-based industries, followed by state agriculture departments and the private sector. The demand for biofertilizer in the Global market is predicted to elevate at a rapid Compound annual growth rate (CAGR) of 12.9% during the period of 2017 to 2025 (Majumdar, 2015) because of a number of factors gaining attraction over the years, such as a gradual shift from the chemical based farming techniques to organic practices, growing awareness of environmental and health benefits, increasing cost of chemical fertilizers and pesticides, etc (Table 8). The rise in the commercialization of biofertilizers is mainly due to the increasing penetration of biofertilizers in the farming and availability of affordable biofertilizers to end users.

It has been estimated that around USD 1.5 billion are being spent by Indian on biofertilizers. Also, organic agriculture occupies more than 100,000 hectares and biofertilizers plays an important role in the expansion and hence their use is also expected to increase over the years. There are over 100 companies producing biofertilizers worldwide and one of the key supplier, Biomax is situated in India (Fraile *et al.*, 2015).

A number of patents are being filed related to biofertilizer every year (Table 9). In the field of patent publication Europe, Japan, USA, India, Brazil and Korea are the eminent countries when it comes to biofertilizer patents.

Table 9. Yearwise Share of Biofertilizer Patents in India (Gomila *et al.*, 2018)

Year	Biofertilizer patents (%)
2006-2007	0.3
2007-2008	0.3
2008-2009	0.5
2009-2010	0.7
2010-2011	0.9
2011-2012	1.0
2012-2013	0.8
2013-2014	0.6
2014-2015	0.7
2015-2016	0.8

Conclusions and Future aspects

Our reliance on pesticides and chemical fertilizers has resulted in the blooming of industries producing hazardous chemicals which is not only precarious for human health but has also polluted the environment. Fortunately, the liking is increasing more towards organic food in contrast to foods grown using chemical fertilizers because of the increasing awareness of their harmful effects. It is utmost important to be aware of the positive aspects of biofertilizers so as to inculcate it in the sustainable agriculture. Biofertilizers having a wide range of potential application can play important role in increasing fertility of soil, productivity and can save the ecosystems as cost effective and environment-friendly inputs are used. With the right amalgamation of biofertilizers and organic based farming sustainability of farming can be achieved.

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