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A case study of bio-inoculants as prospective inputs in India for achieving sustainability

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Abstract
In the present case study, use and major manufacturer /industries involved for production of bio-inoculants in India has been presented. The total number of units including public, private and cooperatives estimated to be 297. Maharashtra is having the highest number of private companies (68) followed by Gujarat (56) while Tamil Nadu have the highest number public sector units (7) and Delhi is having highest number of co-operatives units (3). Production data (carrier base in MT) revealed that Gujarat (6575 MT) topped the list first followed by Madhya Pradesh and Karnataka (2589.9 MT) during 2016-17. Zone wise bio-fertilizer production in India during the same period is highest in Karnataka both in carrier-based formulation (31553.06 MT) and liquid based formulation (993.443 KL).

Keywords: Bio-inoculant, bio-fertilizers, solubilizers, sustainability and integrated

Introduction
Sustainable agriculture is proving as one of the toughest jobs is more or less common is the use of chemical pesticides and fertilizers causing agriculture fatigue. Therefore, it is a matter of concern to overcome nutritional effects through the help of intensification of agriculture with the use of chemical fertilizers, broad spectrum pesticides. Due to the necessity to reduce chemical products (chemical fertilizers, pesticides and supplements), it's the moral responsibility aiming sustainable agriculture and protecting the environment. Integrated plant nutrient management is an important component through rational use of existing technology for sustainable agriculture. The best available options lie in the complementary use of bio-fertilizers and organic matter in suitable combinations with chemical fertilizers (Rakshit *et al.*, 2014). The efficient bio-fertilizers are gaining importance in sustaining agriculture as bio-inoculants may be the most option to overcome from agriculture fatigue due to various complementing combinations of microbial inoculants for management of major nutrients are necessary for agriculture sustainability which are more robust than synthetic chemicals as the formulation product of a single microbe may involve direct interactions with pathogens and numerous mechanisms take part in disease suppression and plant growth promotion. Bio-fertilizers are related commonly to plant growth promotion and responses to abiotic stresses, induced by a pool of bioactive compounds from a great diversity of environment friendly sources (Barman *et al.*, 2017; Meena *et al.*, 2017) [1, 3]. The beneficial bacteria can produce phytohormones and other compounds (Borriss, 2011). Biomasses and their extracts, e.g., algae and yeast or by mycorrhizal fungi, even products obtained by fermentation as amino acid sources, among a huge diversity of sources that nature and the biotechnology can offer. Leguminous crop fixes the atmospheric nitrogen by rhizobium which requires optimum level of phosphorus in plant tissue. Mineral solubilizers play an important role in seedling setting because more of the tropical soils are phosphate fixing and make it unavailable to the plants. Phosphate solubilizing microorganisms (PSMs) that solubilize bound form of phosphorus and AM fungi act as up taker of phosphorus and make it available to the host plants. There is no uniformity in agriculture practices all over the world, but one thing which facilitate plant mineral nutrition by changing the amounts, concentrations and properties of minerals available to plants.

The development of bio-inoculant with multi-crop growth promoting activities is most important for sustenance of agriculture. Instead of being financially viable and eco-accommodating in nature, a few imperatives incorporate temperamental supplies and non-appearance of appropriate quality control limit the application or execution of the innovation.

Bio-pesticides and bio-fertilizers are naturally occurring formulations made from the substances that control pests by nontoxic mechanisms and in ecofriendly manner. Bio-pesticides being a living organism (natural enemies) or products there of pose less threat to the environment and to human health, hence can be used for the management of pests (Barman *et al.*, 2017) [1].

Constantly increasing demand of bio-pesticides and bio-fertilizers offers exciting career for science graduates with a special reference to Agri-graduates and scholars. Entrepreneurships based on production of bio-pesticides and bio-fertilizers have potential to generate large employment and income. However, in spite of fascinating and vast opportunities in this sector, growth and development of the same is not encouraging. In order to process the idea of new start up and entrepreneurship, information is very essential factor. Based on the available information one can formulate and execute his idea of entrepreneuring. Similarly, the start-up plan for setting a bio-pesticides and bio-fertilizers based industry need basic information for troubleshooting various problems.

However, information regarding requirement for establishing a bio-pesticides and bio-fertilizers industry are lacking. Basic information related to available technological options, cost of production, quality control, turnkey solution and IP protection are lacking.

Materials and Methods

Data of present case study was collected by primary and secondary sources.

Primary data: Data or information to help answer questions, understand a specific issue or test a hypothesis. Researchers in the agricultural sciences can obtain their data by getting it directly from the subjects they're interested in.

Secondary Data: Another type of data that may help researchers is the data that has already been gathered by someone else. An advantage of using primary data is that researchers are collecting information for the specific purposes of their study. In essence, the questions the researchers ask are tailored to elicit the data that will help them with their study. Researchers collect the data themselves, using surveys, interviews and direct observations. In the field of workplace agricultural research, for example, direct observations may involve a researcher watching people at work. The researcher could count and code the number of times she sees practices or behaviors relevant to her interest.

Data can be collected from two sources that are internal and external sources. The data collected from internal sources are called primary data whereas the data collected from external sources are called secondary data. The sources of data are shown clearly by the following Figure 1.

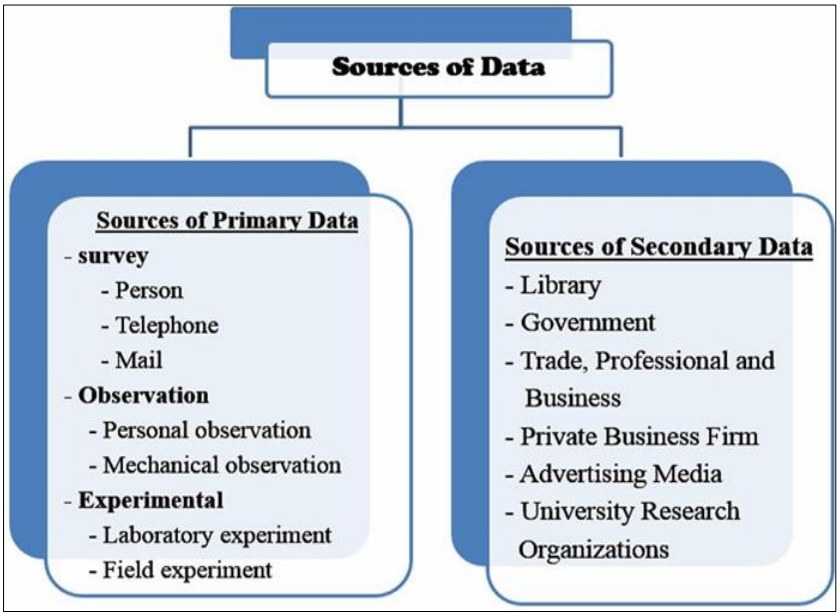

Fig 1: Sources of data

Sources of Primary Data

The data collected for the first time are called primary data. The methods mostly used in collecting primary data are survey, observation and experiment. Generally, all these methods are not used in a same project, because they have both good and bad aspects. The question which method should be selected depends on the nature, time and cost. Or method should be selected according to the nature, time and cost. Primary data sources includes survey, persons/individuals, telephone and mails. However, observation recorded in terms of personal observation, mechanical observation, mechanical observation, experimental observation, laboratory and field and field experiments.

Sources of Primary Data

The data used once are called secondary data. It becomes much easier to collect secondary data than the primary ones. Secondary data can be collected from several sources. The main sources are library, government publications, advertising media and university research organization.

Information sources

Refined and cleansed data is called information. This information becomes useful. Information can be collected from several sources. The main sources are marketing research system, marketing intelligence system, internal record system and marketing decision record system.

Method of data collection

Secondary data will be collected from Ministry of Agriculture and Universities/research institutes web page A team of experts will collect primary data from Agricultural Universities, CSIR Labs, ICAR Labs and other private and public sector organization engage in development of microbial technologies.

Sources of the data

Central Insecticide Board and Registration Committee, Ministry of Agriculture, National Centre for Organic farming, Department of Fertilizer, Ministry of Chemicals and Fertilizer, GoI, Agricultural Universities, CSIR Labs, ICAR Labs.

Results and Discussions

Segmented analysis of different bio-inoculant production units

Various observations and results obtained with the survey conducted during the study period have been documented in this chapter. An attempt was also made to present the data in tabular and graphical form to draw valid conclusions.

As we know that the Indian government has drawn its considerations lately in comparison of developed country but had put big initiatives in collaboration with national institutes to look forth and contributes enhancement of bio-fertilizer productions. Indian bio-fertilizer market had grown rapidly in the period of financial year 2009 till today, the production of bio-fertilizers in India had more than tripled during 2009-18. The growth is expected to continue in future owing to the strong push by the Government of India (GoI) to promote bio-agriculture. From the table and Fig. 2. It is evident that Maharashtra is having highest no. of companies (68) followed by Gujarat (56) as shown in Figure 2.

It is also revealed that there is no setup of commercial biofertilizer production unit in north-eastern states of India as well as in states like Jammu and Kashmir, Ladakh, Bihar and Jharkhand and Union Territory like Puducherry, Lakshadweep, and Andaman and Nicobar Island.

Agritech start-ups initiated for production of low cost bio-fertilizer and bio-pesticide

In order to achieve the goal of doubling the farmers' income by 2022, it is imperative that the potential of agriculture research is optimally realized by extending bio-fertilizers and bio-pesticides production in a manner that leads to new products, services and systems that add value to bring about significant changes in income, employment and livelihood security; not only in rural India but also to fuel the entire economy. In other words, bringing knowledge to create value has to be at the centre of the new approach. This can be achieved if ventures are created in large number and nurtured through appropriate interventions/incentives/investments by generating new technologies, allowing access to latest technologies, arranging required services and supplies to optimally use the technologies, and providing the required venture skills. This requires setting up of an effective start up system that nurtures venture development. Realizing the need for support and nurturing the techno-entrepreneurs has been taken up in the Agribusiness startups established through ICAR institutes or self-monitored, keeping in view, the spectrum of technologies, available infrastructure and the core competency of the institutes. There are many emerging technologies and up-and-coming startups working on solutions for the agriculture sector. As there is a large number of startups working on a wide variety of solutions including promising bio-fertilizer solutions.

For this study, there are identified region specific relevant solutions and were chosen based on a data-driven startup scouting approach, taking into account factors such as location, founding year, technology, and mentoring institutes such as CSIR Labs, ICAR, IITs and other research institutes among others.

Table 1: Number of private companies engaged for producing bio fertilizers in different states of India

S. No.	STATS/Uts	No of companies
East Zone		
1.	Bihar	0
2.	Jharkhand	0
3.	Odisha	3
4.	West Bengal	9
Mean		3
Median		1.5
North east		
5.	Sikkim	0
6.	Arunachal Pradesh	0
7.	Assam	0
8.	Manipur	0
Mean		0
Median		0
West Zone		
9.	Goa	0
10.	Gujrat	56
11.	Maharashtra	68
12.	Daman and Diu	0
13.	Dadra Nagar Haveli	0
14.	Chhattisgarh	2
15.	Nagar Haveli	0
16.	Madhya Pradesh	10
17.	Rajasthan	5
Mean		15.66
Median		2
North Zone		
18.	Haryana	8
19.	Punjab	12
20.	Himachal Pradesh	1
21.	Uttar Pradesh	5
22.	Uttarakhand	7
23.	Delhi	13
24.	Chandigarh	0
25.	Jammu and Kashmir	0
26.	Ladakh	0
Mean		5.11
Median		5
South Zone		
27.	Andhra Pradesh	11
28.	Telangana	0
29.	Karnataka	22
30.	Kerala	7
31.	Tamil Nadu	54
32.	Puducherry	0
33.	Lakshadweep	0
34.	Andaman and Nicobar	0
Mean		11.75
Median		3.5

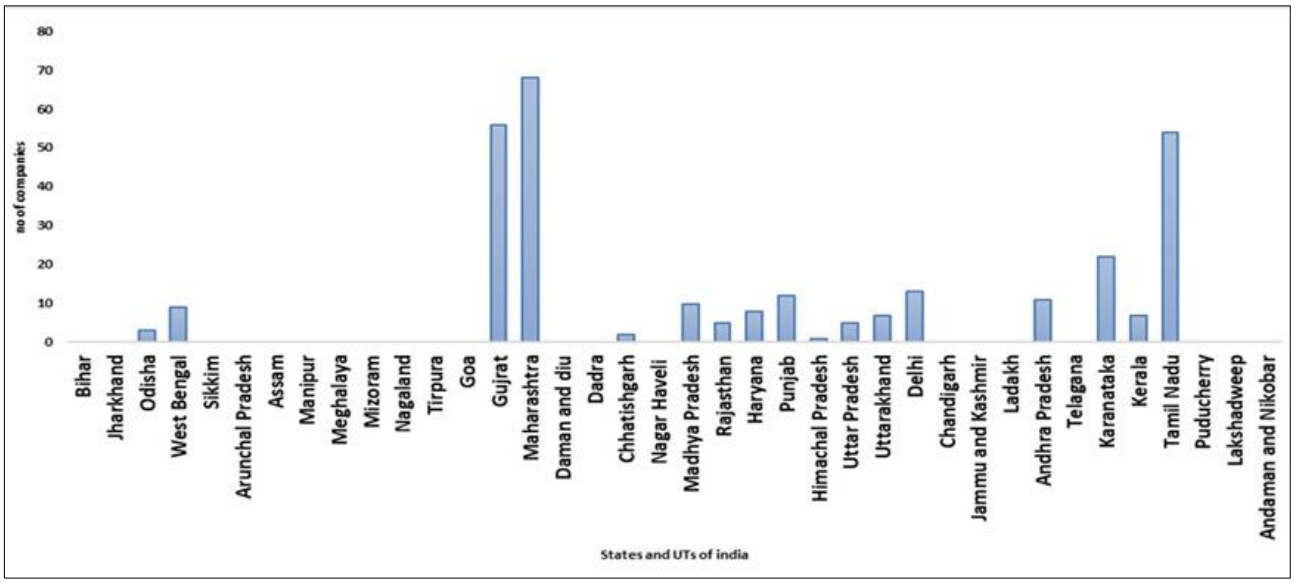

Fig 2: Number of private companies engaged for producing bio fertilizers in different states of India

Table 2: Further it was found that in the category of public sector, private & co- operative engaged for producing bio fertilizers in different states of India revealed that Tamil Nadu have the highest no. public sector companies (7) and Delhi is having largest number of co-operative units (3) as indicated in Figure 3

Stats/Uts	Types of Companies		
	Number of Public sector Companies	Number of private Sector Companies	Number of Co- Operative
East Zone			
Bihar	-	-	-
Jharkhand	-	-	-
Odisha	-	3	-
West Bengal	-	9	-
Mean	0	3	0
Median	0	1.5	0
North East Zone			
Sikkim	-	-	-
Arunchal Pradesh	-	-	-
Assam	-	-	-
Manipur	-	-	-
Meghalaya	-	-	-
Mizoram	-	-	-
Nagaland	-	-	-
Tripura	-	-	-
Mean	0	0	0
Median	0	0	0
West Zone			
Goa	-	-	-
Gujrat	1	55	-
Maharashtra	-	68	-
Daman and diu	-	-	-
Dadra Nagar havali	-	-	-
Chhattisgarh	-	2	-
Nagar Haveli	-	-	-
Madhya Pradesh	1	8	-
Rajasthan	-	4	-
Mean	0.222222	15.22222	0
Median	0	2	0
North Zone			
Haryana	1	6	-
Punjab	-	12	-
Himachal Pradesh	-	1	-
Uttar Pradesh	-	5	-
Uttarakhand	-	6	-
Delhi	1	9	3
Chandigarh	-	-	-
Jammu and Kashmir	-	-	-

Ladakh	-	-	-
Mean	0.22222222	4.333333	0.333333
Median	0	5	0
South Zone			
Andhra Pradesh	-	10	-
Telangana	-	-	-
Karnataka	-	21	-
Kerala	-	7	-
Tamil Nadu	7	46	1
Puducherry	-	-	-
Lakshadweep	-	-	-
Andaman and Nicobar	-	-	-
Mean	0.875	10.5	0.125
Median	0	3.5	0

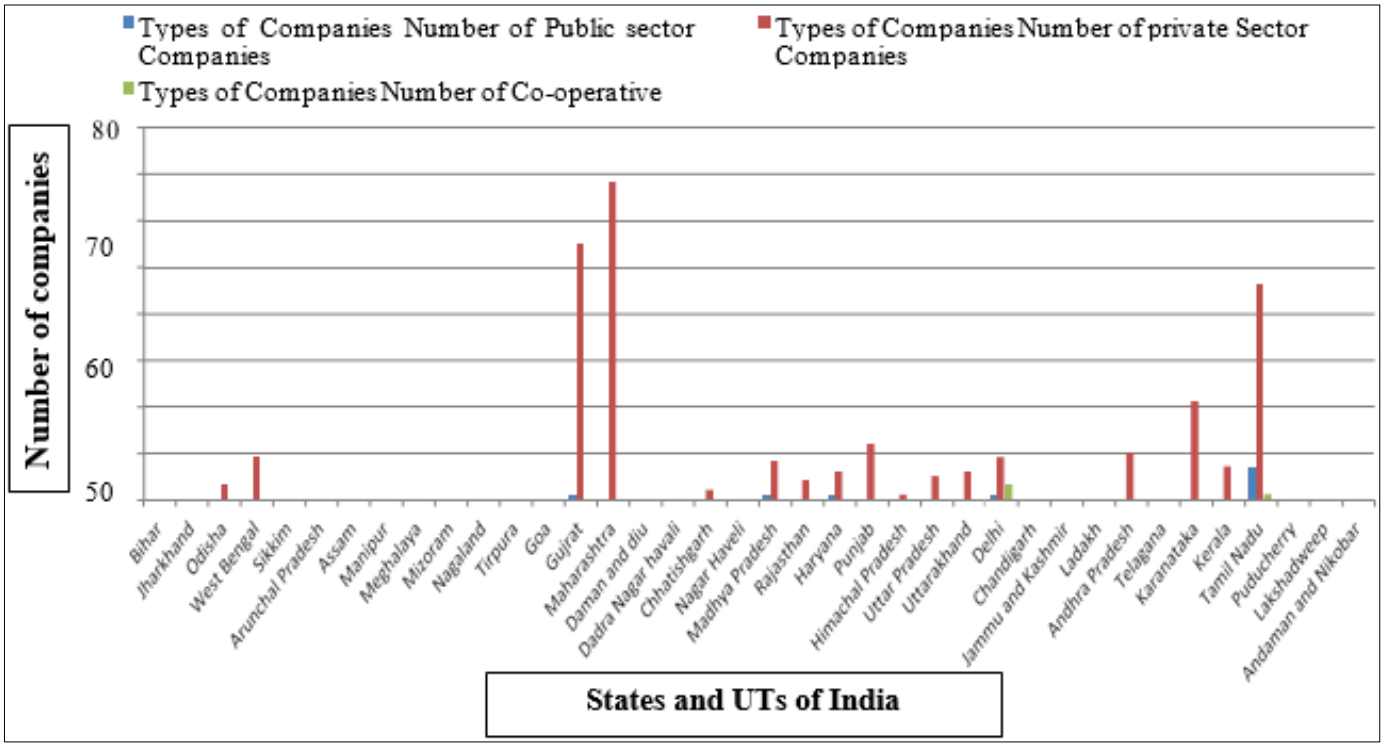

Fig 3: Break up of different organization (public, private and co-operatives) in different states of India

Table 3: Inoculant wise biofertilizer production (carrier base) (MT) in different State/UT of India during 2016-17 is highest in Gujarat i.e., 6575 MT followed by Madhya Pradesh and Karnataka 2589.9 as shown in Figure 4

States/UTS	Capacity	*Azotobacter*	*Azospirillum*	*Rhizobium*	PSB	KMB	ZSB	VAM	*Acetobacter*	NPK		
										Consortium	Others	Total
Himachal Pradesh	450	20	-	5	24.5	21	20	3.9	-	50.2	50.1	194.7
Delhi	-	-	-	-	-	-	-	-	-	-	-	-
Uttarakhand	1400	91.38	15.35	28.75	36.03	15.2	15.2	28.8	-	230.48	-	461.19
Uttar Pradesh	380	177.57	3.9	-	333.1	17.01	3.08	-	21.18	139.82	1.24	696.9
Sikkim	-	-	-	-	-	-	-	-	-	-	-	-
Assam	1400	3	-	-	3	20	-	-	-	-	-	26
Arunachal Pradesh	-	-	-	-	-	-	-	-	-	-	-	-
Manipur												
Meghalaya	1745	27.772	10.36	25.29	131.869	9.774	9.838	-	7.31	2.39	13.5	238.103
Mizoram	866	67.75	41.97	63.82	86.52	64.33	0	19.88	17.7	11.37	24.99	398.33
Nagaland	-	-	-	-	-	-	-	-	-	-	-	-
Tripura	-	-	-	-	-	-	-	-	-	-	-	-
Punjab	-	-	-	-	-	-	-	-	-	-	-	-
Chandigarh	-	-	-	-	-	-	-	-	-	-	-	-
Haryana	1590	5.078	0.05	6.6	10.04	14.82	1.37	-	0.09	32.1	-	70.148
Rajasthan	1350	8.958	6.729	6.89	7.713	0.7	0.8	-	-	-	-	31.79
	1870	46.61	15.16	14.204	34.261	11.13	1.61	0.062	0.67	86.47	-	210.177
Gujarat	6575	472.51	289.59	188.74	572.51	338.6	26.45	-	86.33	668.04	215	2857.77
Maharashtra	184.5	7.264	9.0781	14.7958	15.164	7.3124	-	6	-	-	-	59.6143

Goa	-	-	-	-	-	-	-	-	-	-	-	-
Dadra & Nagar Haveli	-	-	-	-	-	-	-	-	-	-	-	-
Daman & Diu	-	-	-	-	-	-	-	-	-	-	-	-
Lakshadweep	-	-	-	-	-	-	-	-	-	-	-	-
Madhya Pradesh	2589.9	51.946	419.783	90.569	7	7	5	-	-	85.796	2.35	993.443
Chhattisgarh	800	0.5	1.48	0.19	2.63	2.04	1.89	-	-	1.5	-	10.23
Bihar	-	-	-	-	-	-	-	-	-	-	-	-
West Bengal	120	4.09	0.95	8.58	9.87	0.97	0.5	0.4	-	0.85	-	26.21
Odisha	-	-	-	-	-	-	-	-	-	-	-	-
Pondicherry	1100	1.194	1.393	0.33	2.42	2.6	0.73	-	1.26	0.92	0.35	11.197
Andhra Pradesh	670	92.9	2.69	10.99	208.02	33.22	3.5	2.6	3.5	3.52	4.3	365.24
Telangana	-	-	-	-	-	-	-	-	-	-	-	-
Karnataka	2589.9	51.946	419.783	90.569	7	7	5	-	-	85.796	2.35	993.443
Kerala					191.98	102.62	48.38					
Tamil Nadu	2278.5	18.896	171.371	55.132	514.92	46.407	12.442	3.3	7	8.54	37.32	875.292
Andaman & Nicobar	-	-	-	-	-	-	-	-	-	-	-	-
Grand Total	25368.9	1097.418	989.8541	519.8808	2184.536	707.744	145.777	64.942	145.04	1321.996	349.15	7536.334

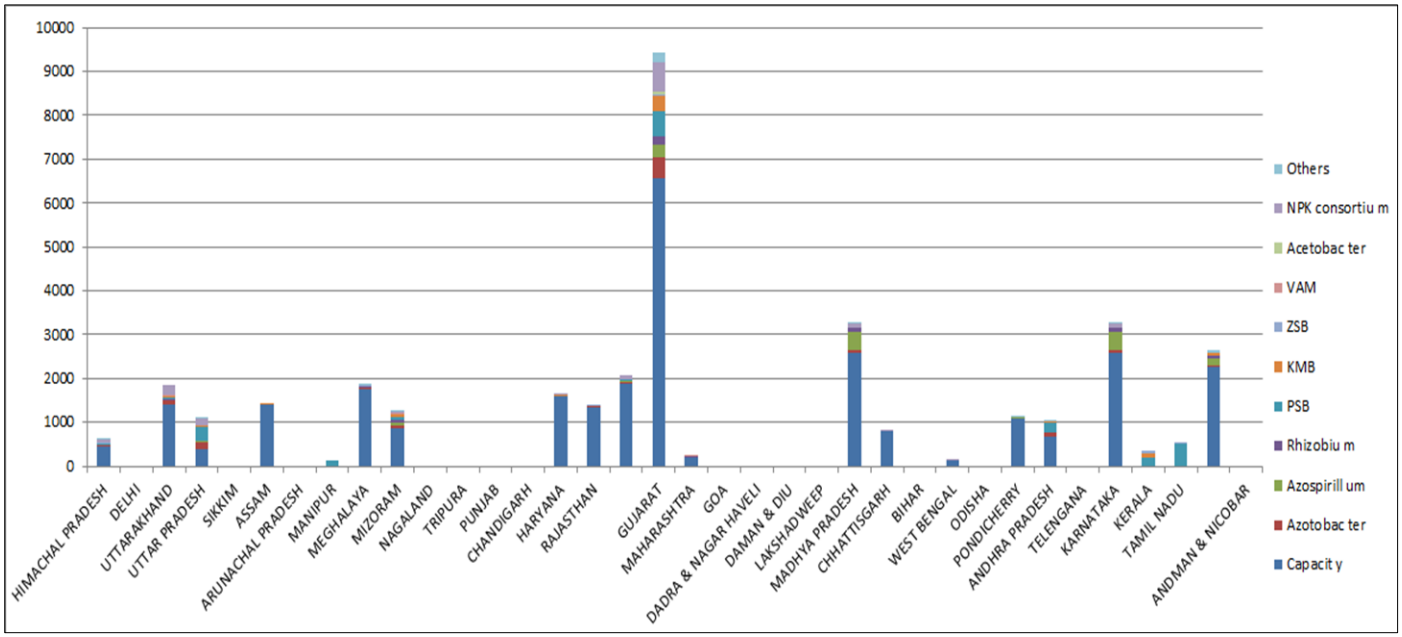

Fig 4: Inoculant wise biofertilizer production (carrier base) (MT) in different State/UT of India during 2016-17

Table 4: Zone wise bio-fertilizer production in India during 2008 to 2017

S. No.	State	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15		2015-16		2016-17	
		Carrier based (MT)	Carrier based (MT)	Carrier based (MT)	Carrier based (MT)	Carrier based (MT)	Carrier based (MT)	Carrier based (MT)	Liquid based (KL)	Carrier based (MT)	Liquid based (KL)	Carrier based (MT)	Liquid based (KL)
South zone													
1	A & N Islands	—	—	—	—	—	—	—	—	—	—	—	—
2	Andhra	168.13	1345.28	999.60	1126.35	1335.74	2714.22	2668.80	274.85	3062.6	317.81	3375.91	365.24
3	Daman &Diu	—	—	—	—	—	—	—	—	—	—	—	—
4	Karnataka	11921.05	3695.50	6930.00	5760.32	7683.72	9907.33	16462.62	23.05	23042.91	488.14	31553.06	993.44
5	Kerala	1187.00	1936.45	3257.00	904.17	1045.64	3520.66	4916.97	10.50	4926.04	56.57	4993.86	59.61
6	Lakshadweep	—	—	—	—	—	—	—	—	—	—	—	—
7	Pondicherry	561.79	452.79	783.00	509.45	621	516.98	560.95	1.49	283.64	4.08	203.96	11.19
8	Tamil Nadu	4687.81	3732.59	8691.0	3373.81	11575.7	14104.83	15373.29	11.30	23721.21	861.95	27427.96	875.29
	Total	18525.80	11162.61	20660.60	11674.1	22261.8	30764.02	39982.63	321.22	55036.41	1728.57	67554.76	2304.78
	Mean	3705.16	2232.52	4132.12	2334.82	4452.36	6152.80	16462.62	64.2442	11007.28	345.71	13510.95	460.95
	Median	1187.00	1936.45	3257	1126.35	1335.74	3520.66	4916.97	11.3017	4926.04	317.81	4993.86	365.24
West zone													
1	Chhattisgarh	—	—	—	276.34	501.63	712.07	1024.68	9.620	954.371	9.38	955.074	10.23
2	Gujarat	1149.69	1309.19	6318.00	2037.35	978.48	6411.43	3667.92	2800.50	3963.42	2873.31	3909.82	2857.77
3	Goa	—	—	—	—	370	66.26	802.52	—	820.52	—	822	—
4	Madhya	848.44	1587.68	2455.57	2309.06	1408.08	4824.19	2637.99	119.21	2741.30	131.03	5609.00	238.10
5	Maharashtra	1249.87	1861.33	2924.00	8743.69	5897.91	6218.60	14847.39	324.76	7825.14	389.66	8323.61	398.33
6	Rajasthan	353.67	805.57	819.75	199.78	982	1315	599.89	0.000	680	—	711	—
7	D & N Haveli	—	—	—	—	—	—	—	—	—	—	—	—
	Total	3601.68	5563.77	12960.72	13566.22	10138.10	19547.56	23580.41	3254.10	16984.76	3403.39	20330.51	3504.43
	Mean	817.32	1390.94	3129.33	2713.24	1689.33	3257.92	3930.06	650.82	2830.79	850.84	2401.38	876.10

	Median	848.44	1448.43	2689.78	2037.35	980.24	3069.59	1831.33	119.21	1847.83	260.34	955.07	318.21
North zone													
1	Delhi	1165.1	1021.85	1205.00	1617	—	396	104.50	—	106.2	—	116.2	—
2	Chandigarh	—	—	—	—	—	—	—	—	—	—	—	—
3	Haryana	14.25	6.20	6.53	914.41	5832.61	1146.48	872.95	46.48	1097.45	58.03	2360.64	70.14
4	H.P.	—	8.50	9.00	1.29	—	26.14	0.76	33.07	2.712	190.05	3.27	194.7
5	J & Kashmir	—	—	—	—	—	45.26	—	—	—	—	—	—
6	Punjab	1.14	301.23	2.50	692.22	2311.33	2124.85	6305.45	74.27	2197.19	149.58	5533.77	210.17
7	Uttar Pradesh	885.51	962.64	1217.45	8695.08	1310.02	2682.22	4099.06	98.03	3053.11	223.34	2835.79	461.19
8	Uttarakhand	48.23	32.00	45.00	263.01	2758.21	5493.85	2129.95	208.03	3549.39	428.22	3720.68	696.9
	Total	2114.23	2332.42	2485.48	12183.1	12212.17	11914.81	13512.69	459.90	10006.07	1049.22	14570.36	1633.11
	Mean	817.32	1390.94	3129.33	2713.24	1689.33	3257.92	3930.06	650.82	2830.79	850.84	2401.38	876.10
	Median	848.44	1448.43	2689.78	2037.35	980.24	3069.59	1831.33	119.21	1847.83	260.34	955.07	318.21
East zone													
1	Bihar	—	—	136.26	75	52.4	52.4	64.90	0.00	97.00	—	107.00	—
2	Jharkhand	15.00	15.00	0.00	8.38	35.3	14.2	9.08	0.00	9.17	—	18.55	—
3	Odisha	405.03	289.87	357.66	590.12	407.1	1097.61	1074.46	4.70	467.63	13.70	516.28	31.79
4	West Bengal	241.24	256.50	393.39	603.2	1110	1682.70	2061.83	14.63	2826.27	23.53	3195.18	26.21
	Total	661.27	561.37	887.31	1276.7	1604.8	2846.91	3210.27	19.33	3400.07	37.23	3837.01	58
	Mean	220.42	187.12	221.82	319.17	401.2	711.72	802.56	4.83	850.01	18.61	959.25	29
	Median	241.24	256.5	246.96	332.56	229.75	575.00	569.68	2.35	282.31	18.61	311.64	29
North east zone													
1	Arunachal	—	—	—	—	—	59	59	—	3062.6	317.81	119.7	—
2	Assam	129.35	121.04	130.00	68.33	89	149	88.00	—	1315	22.5	1359.05	26
3	Manipur	—	—	—	—	—	—	—	—	—	—	25	—
4	Meghalaya	—	—	—	—	—	—	—	—	—	—	—	—
5	Mizoram	1.99	2.50	2.00	—	—	4	3.60	—	4.2	—	2.5	—
6	Nagaland	16.00	18.25	21.50	13	7.45	7.45	7.45	—	8.81	—	51.45	—
7	Sikkim	—	—	—	—	9.5	10.1	12.40	—	12.91	—	16.25	—
8	Tripura	14.68	278.40	850.00	1542.85	514	225	240.00	—	1143.07	—	1153.5	—
	Total	162.04	420.19	1003.50	1624.18	619.95	454.55	410.45	—	5546.59	340.311	2727.45	26
	Mean	40.51	105.047	250.87	541.39	154.98	75.75	68.40	—	924.43	170.15	389.63	3.25
	Median	15.34	69.64	75.75	68.33	49.25	34.55	35.7	—	577.99	170.15	51.45	0

Conclusion

In the present study, use and major manufacturer /industries involved for production of bio-inoculants in India has been presented. The total number of units including public, private and cooperatives estimated to be 297. Maharashtra is having the highest number of private companies (68) followed by Gujarat (56) while Tamil Nadu have the highest number public sector units (7) and Delhi is having highest number of co-operatives units (3). Production data (carrier base in MT) revealed that Gujarat (6575 MT) topped the list first followed by Madhya Pradesh and Karnataka (2589.9 MT) during 2016-17. Zone wise bio-fertilizer production in India during the same period is highest in Karnataka both in carrier-based formulation (31553.06 MT) and liquid based formulation (993.443 KL).

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