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The Biopesticide Landscape in India: Current Status

R. Venkat Ramchandar,

Assistant Professor of Microbiology, Tara government College (Autonomous), Sangareddy, Telangana, India
Email: 23venkat73@gmail.com

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ABSTRACT

India's biopesticides market is changing quickly due to shifting consumer preferences, growing international agricultural commerce, and shifting regulations. Currently, 5% of India's pesticide market is made up of biopesticides. The biopesticides market in India is expected to grow at a 9.5% compound annual growth rate (CAGR) from its estimated value of USD 242.16 million in 2025 to USD 381.23 million by 2030. There are 970 bio registrants in India with 28 different biopesticides. These include (a) microbial biopesticides such as (i) entomopathogenic fungi biopesticides (ii) antagonistic bacteria biopesticides (iii) antagonistic fungi biopesticides (iv) entomotoxic bacteria biopesticides and (v) baculo virus biopesticides and (b) botanical biopesticides under (i) eucalyptus extract containing eucalyptol biopesticides,(ii) rotenone containing biopesticides for pisciculture (iii) Cymbopogon extract containing biopesticides (iv) pyrethrum extract containing biopesticides (v) herbal plant growth regulators (vi) Neem based products containing azadirachtin for house hold uses biopesticides (vii) Neem based products as biopesticides etc. Because of their generally lower environmental impact and ability to promote ecological balance, biopesticides are widely considered a sustainable non-conventional alternative or supplement to conventional chemical pesticides. They offer unique advantages that address several problems associated with synthetic substances. Biopesticides are the cornerstone of integrated pest management (IPM) strategies because, in contrast to chemical pesticides, they degrade quickly in the environment and may not last longer (reduced environmental persistence), are highly specific to target pests, preserve biodiversity without harming nontarget pests, and pose little to no risk to humans and animals.

1.Introduction

The agriculture sector in India contributes around 18% to the country's GDP. The agriculture sector contributed approximately 17.8% to GDP in 2023-24 and 17.94 % (18%) in 2024-2025 [1,2,3]. India possesses the world's second-largest arable land area, spanning over 150 million hectares [4]. Agriculture continues to be a crucial sector, providing a primary source of livelihood for nearly 55% of the population, even as its share of the overall GDP has decreased over the decades [5]. Creative approaches are necessary to satisfy the constantly rising needs for food and fibre due to the rapidly increasing population of India. These requirements

can solely be fulfilled by protecting crops from pest damage while preserving scarce natural resources and sustaining maintaining environmental quality. Biological control (BC) is a crucial element of integrated pest management (IPM) approaches. It utilizes natural enemies of pests and pathogens; predators, parasites, and microbes to control pest numbers, thus decreasing dependence on synthetic pesticides.[6]. Biopesticides are currently becoming more and more popular because their application in sustainable agricultural production models like organic agriculture which avoids the use of synthetic pesticides or phytosanitary agents [7]. Similarly, bio-pesticides are used in Integrated Pest Management (IPM) to reduce environmental risk [8]. Because of their natural origin, minimal toxicity, and rapid decomposition, biopesticides are regarded as environmentally friendly products.

2.Research Methodology

This review article adopts a systematic qualitative research methodology aimed to analyse scenario of biopesticides in India. This approach integrates a structured literature review, comprehensive and balanced assessment of the topic. Relevant literature and data were collected from different literature sources, including Peer-reviewed journals: Sourced from Scopus, Science Direct, Springer, Wiley Online and Taylor & Francis databases. Institutional reports: IPCC, World Bank, Data from Directorate of Plant Protection, Quarantine & Storage Ministry of Agriculture and Farmers Welfare, Ministry of Health and Family Welfare, Ministry of Environment, Forest and Climate change, press information bureau, Government of India etc Over 68 documents were primarily screened, of which 48 were selected and included in the final review based on relevance, quality, and data richness.

3.Review and Analysis

Agricultural pests and types of pesticides

The International Plant Protection Convention (IPPC) defined pest as species, strain, biotype of pathogen or plant or animal or causing injury to the plants or products of plants [9]. Crop plants are unfairly affected by different organisms such as bacteria, fungi, viruses, insects, nematodes, weeds etc resulting in lower yield and lower quality in agricultural products. Plant pests comprise insects like aphids, caterpillars, earwigs, slugs, snails, birds, nematodes, bacteria, fungi, Oomycetes, viruses and viroids. Pesticides are any chemical substances or biological components or their mixtures used for control or kill or repulsion of any pest, or plant growth regulators [10]. Pesticides are the chemicals employed for control and management, prevention of plant diseases, protection from plant pathogens, weeds, pests and to enhance the quality of the food

products. Pesticides are classified into insecticides, acaricides, algicides, antifeedants, avicides, bird repellents, bactericides, fungicides, virucides, chemosterilants, insect attractants, insect repellents, insecticides, mammal repellents, mating disrupters, molluscicides, nematicides, rodenticides, plant growth activators and regulators, synergists, miscellaneous chemical classes etc. [11]. Overdependence on synthetic chemical pesticides to control pests are nonspecific to target organisms and has detrimental effect on humans, animals, environment. More than 1000 pesticides are used around the world to protect crop plants and ensure food from damage by pests [12].

Black list of Internationally banned synthetic chemicals

Chemical pesticide use in Indian agriculture has sharply increased in recent years, with grave consequences for groundwater, the environment, and human health. Therefore, finding an environmentally benign alternative to chemical pesticides has become crucial. In addition to being regarded as the next generation of pesticides, biopesticides are seen to offer enormous potential to advance sustainable agriculture in this nation. Some developed nations have placed stringent restrictions on the use and sale of synthetic pesticides due to the occurrence of greater pesticide residues in food crops and growing pest resistance.

Since the EPA was formed in 1970, 134 agricultural pesticides have been discontinued in the U.S. Of these, only 37 were due to non-voluntary, EPA-initiated cancellations, while the remaining 97 were voluntarily withdrawn by the registrants [13]. Examples of major pesticides that were subject to EPA-initiated bans include: DDT (banned in 1972), Aldrin, Dieldrin, Chlordane, Toxaphene, Carbofuran (most uses banned in 2009), Chlorpyrifos (banned for use on food crops in 2022).

The U.S. Food and Drug Administration (FDA) has moved to eliminate the use of medically important antibiotics (those also used in human medicine, such as penicillin and tetracyclines) for enhancing growth in livestock, encouraging judicious use under veterinary oversight. [14,15]. Specific antibiotics like **chloramphenicol, carbadox, nitrofurans, and fluoroquinolones** are prohibited from being used in certain food-producing animals due to health risks and the potential for antibiotic resistance [16]. Two antibiotics, **oxytetracycline and streptomycin**, are still approved for use as pesticides on certain fruit crops in the U.S., despite being classified as "critically" and "highly" important for human medicine by

the World Health Organization (WHO) and being banned for use in agriculture in some other nations like the EU.

India's Pesticide Blacklist: A Step Towards Sustainable Farming.

India ratified the Stockholm Convention on Persistent Organic Pollutants (SCPOPs) on January 13, 2006, after signing it on May 14, 2002 [17]. This convention is an important, legally binding international agreement designed to protect the environment and human health from some of the most dangerous substances on the planet. After ratifying the Stockholm Convention, the Indian government has taken several significant steps to implement its obligations, primarily through robust regulatory frameworks and national action plans. India prepared and submitted its first NIP in April 2011, outlining a strategy to address the initial 12 POPs (the "dirty dozen"). These are (i)synthetic pesticides; Aldrin, Chlordane, DDT (Dichlorodiphenyl trichloro ethane), Dieldrin, Endrin, Heptachlor, Hexachlorobenzene (HCB), Mirex Toxaphene, (ii)industrial chemicals; Polychlorinated Biphenyls (PCBs) and (iii) unintentionally produced industrial byproducts; Polychlorinated dibenzo-p-dioxins (Dioxins), Polychlorinated dibenzofurans (Furans) [17,18].

The Ministry of Environment, Forest and Climate Change (MoEFCC) notified the **"Regulation of Persistent Organic Pollutants Rules"** in March 2018 under the Environment (Protection) Act, 1986. These rules domestically prohibit the manufacture, trade, use, import, and export of several listed POPs. The seven compounds that the Government of India banned through the 2018 POPs rules include a mix of pesticides and industrial chemicals (specifically, flame retardants and solvents/by-products). These are (i) Chlordecone (pesticide) (ii) Pentachlorobenzene (pesticide and industrial chemical) and (iii) Hexabromobiphenyl (iv) Hexabromodiphenyl ether and heptabromodiphenyl ether (commercial octa-BDE) (v) Heptabromodiphenyl ether and pentabromodiphenyl ether (commercial penta-BDE) (vi) Hexabromocyclododecane, (vii) Hexachlorobutadiene [19]. In October 2020, the Union Cabinet approved the ratification of these seven specific chemicals, demonstrating a commitment to formalize domestic regulations and enabling India to access international financial resources (GEF) for implementation [20].

As of late 2024 and 2025, India has a dynamic regulatory environment for these

chemicals, with approximately 49 chemical pesticides banned for manufacture, import, and use, and various bans on antibiotics, particularly for animal use to prevent antimicrobial resistance in humans. As of March 31, 2024, the Indian government has banned the manufacture, import, and use of at least **49 pesticides** [21,22]. This number reflects an accumulation of bans over several years based on recommendations from expert committees. The list of banned pesticides includes: Alachlor, Aldicarb, Aldrin, Benzene hexachloride, Dichlorvos, Endosulfan, Heptachlor, Methyl parathion, Phorate, Triazophos, Trichlorfon. In a significant move in September 2025, the Health Ministry banned 34 antimicrobials (including **15 antibiotics** and 18 antivirals) for use in animals to preserve their efficacy for human medicine. The Indian Health Ministry officially banned the import, manufacture, sale, and distribution of 34 specific antimicrobials for animal use as of September 23, 2025, to combat antimicrobial resistance (AMR) and preserve their efficacy for human medicine [23]. The ban, based on recommendations from the Drugs Technical Advisory Board (DTAB) and aligned with EU regulations, includes 15 antibiotics/antibiotic groups, 18 antivirals, and one antiprotozoal drug. Banned Antibiotics include Ureidopenicillins, Ceftobiprole, Ceftaroline, Siderophore cephalosporins, Carbapenems, Penems, Monobactams, Glycopeptides, Lipopeptides, Oxazolidinones, Fidaxomicin, Plazomicin, Glycylcyclines, Eravacycline, Omadacycline. Banned Antivirals include Amantadine, Baloxavir, marboxil, Celgosivir, Favipiravir, Galidesivir, Lactimidomycin, Laninamivir, Methisazone, Metisazone, Molnupiravir, Oseltamivir, Peramivir, Ribavirin, Rimantadine, Tizoxanide, Triazavirin, Umifenovir, Zanamivir. Banned antiprotozoal Include Nitazoxanide.

India has imposed a complete ban on the use of a combination of streptomycin and tetracycline in agriculture, effective from January 1, 2024, due to concerns over antimicrobial resistance (AMR), particularly as streptomycin is a critical drug for treating tuberculosis in humans. **Streptomycin** is one of the most commonly used antibiotics in plant agriculture globally (e.g., in the US, Canada, and Mexico for fire blight control). However, due to widespread resistance and its importance in human medicine (as a treatment for tuberculosis), its use is prohibited in the EU, and India implemented a complete ban in 2024[24]. The government noted that safer alternatives are available for these drugs in veterinary and agriculture use, and their continued application in plants and animals posed a significant risk to human

health through the development of drug-resistant infections.

Biopesticides

Preferably pesticide should be lethal to the target organisms such as insect pests, bacteria, fungi, viruses, weeds and should not cause damage to human beings and the environment. The ideal pesticide would be cheaper, easily available, should have highly specific action only on target pest, speedy action and easily biodegraded to nontoxic, harmless end products in environment [25]. Most of the available chemical pesticides destroy non target organisms along with target organisms, non-biodegradable persists on crop and crop products and environment [26,27,28] Because of the above drawbacks of synthetic pesticides, biopesticides, an alternative means of pest control is being encouraged.

Biopesticides are usually less toxic, target specific, environment friendly, safe to the beneficial insects and humans, easily decomposed in environment, in most instances effective in small quantities and can be employed in integrated pest management programs to minimize usage of conventional chemical pesticides.

Biopesticides are eco-friendly pesticides derived from natural sources like animals, plants, bacteria, and certain minerals [29,30]. Biopesticides include naturally occurring substances that control pests (biochemical pesticides), microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants) [29,30].

The evolution of biopesticides and milestones

Early farmers in Egypt, Greece, and Rome used basic methods like crop rotation and manual removal of pests. Cats were used to manage rodents in grain storage as far back as 3000 BC. Traditional use of natural substances like neem for pest control existed for centuries. The use of nicotine to control plum beetles as early as the 17th century suggests that plant extracts were the earliest plant disease control agents [31,32]. Now leaf and seed extract of neem is extensively used as biopesticide specifically against insect pests. Neem oil was used in the form of spray to control the spread of *Erwinia amylovora* infection (fire blight disease) in fruits and ornamental plants of Rosaceae including apples and pears. A few of the botanical compounds with pesticidal activity that have been extracted, purified and commercialized successfully include azadirachtin from neem (*Azadirachta indica*) and pyrethrin from pyrethrum (*Tanacetum cinerariifolium*) [32].

Use of botanicals as biopesticides is now emerging as one of the important means to be used in protection of crop products and the environment from pesticidal pollution. Usage of Microbial biopesticide began in the late 19th century with fungal spores used to control insect pests. First usage of biopesticide was reported by Agostino Bassi, in 1835. He showed that spores of the white-muscadine fungus (*Beauveria bassiana*) were able to protect silkworms from muscardine disease [33,34]. Since then, biopesticide use has continued uninterrupted, but to date it has been a small market compared to conventional crop protection by using chemical pesticides. *Bacillus thuriengensis* (Bt) was isolated in pure culture from a diseased silkworm with sotto disease by Japanese biologist Shigetane Ishiwata in 1901. The first commercially available Bt product, sporeine, appeared in France in 1938 and in the US in the 1950s, and then all over the world [35]. Extensive usage of the microorganisms to control and management of plant pathogens started with the control of crown gall disease caused by *Agrobacterium tumefaciens* with *Agrobacterium radiobacter* K84, usage of *Trichoderma harzianum, Gliocaladium virens* and *Streptomyces griseus* (*to* control that of blight diseases in seedlings caused by *Pythium* and *Rhizoctonia.* [36,37,38].

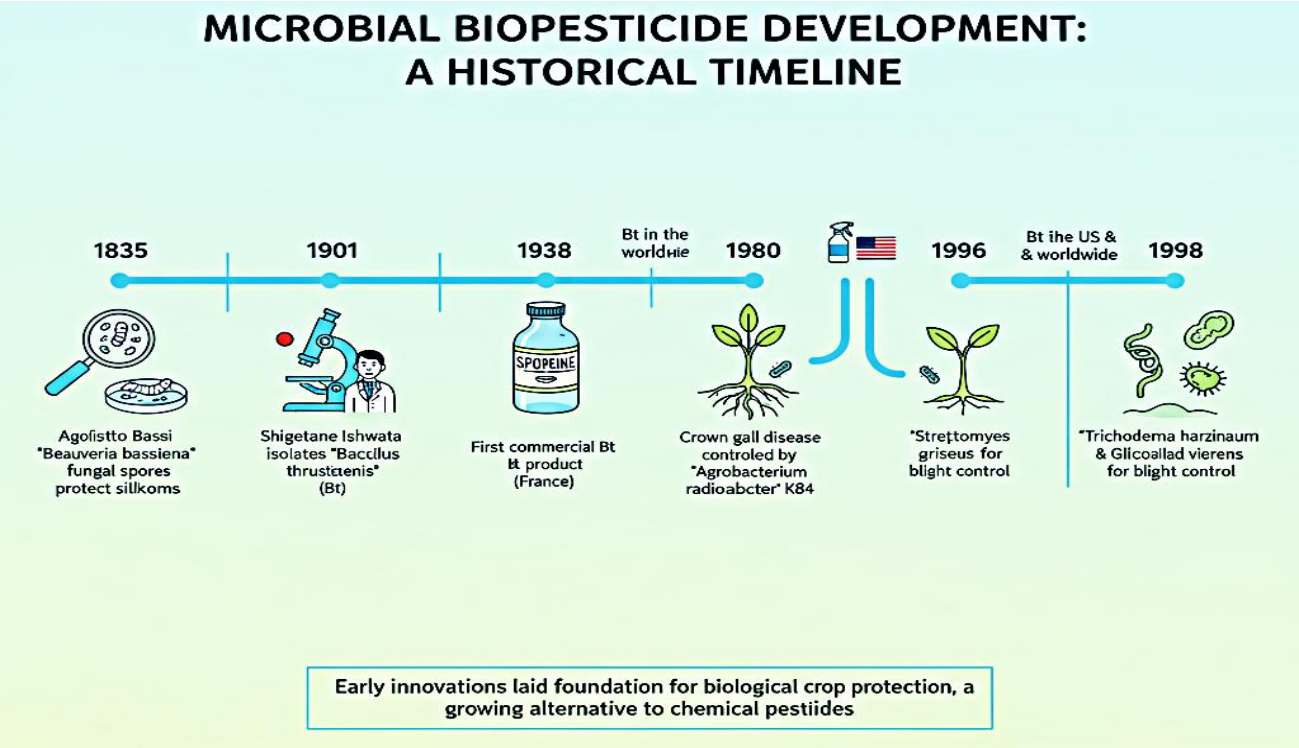


Figure.2 Microbial Biopesticide Development, Early innovations, foundation for biological crop protection: A historical Timeline

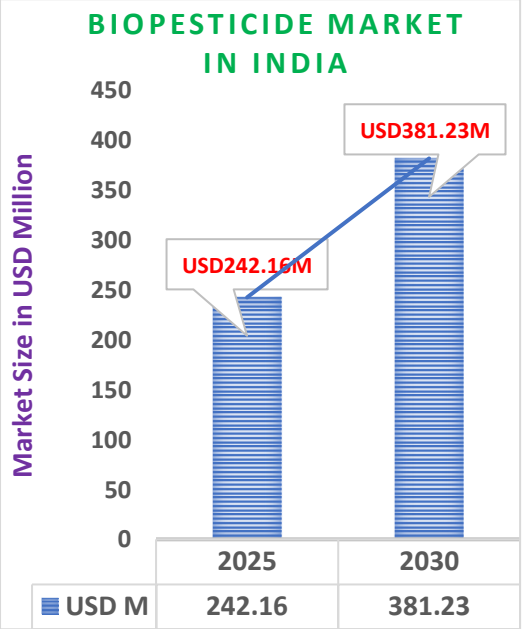
Current status of biopesticides in India

The environmentally friendly nature of biopesticides, policies that encourage public support, rising public awareness, and a decrease in the development of pest resistance are the factors propelling the growth of the Indian biopesticide market. At present more than 970 biopesticide products have been registered with Central Insecticide Board and Registration Committee (CIB & RC) which is a governing body for insecticide registration in India and are available in the Indian market [39]. These include (a) microbial biopesticides such as (i) entomopathogenic fungi biopesticides (ii) antagonistic bacteria biopesticides (iii) antagonistic fungi biopesticides (iv) entomotoxic bacteria biopesticides and (v) baculo virus biopesticides and (b) botanical biopesticides under (i) eucalyptus extract containing eucalyptol biopesticides,(ii) rotenone containing biopesticides for pisciculture (iii) Cymbopogon extract containing biopesticides (iv) pyrethrum extract containing biopesticides (v) herbal plant growth regulators (vi) Neem based products containing azadirachtin for house hold uses biopesticides (vii) Neem based products as biopesticides etc. Different biopestides registered in India are listed below.

Table 1. Various categories of biopesticides registered in India under the Insecticide Act of 1968 by the Central Insecticide Board and Registration Committee (CIB&RC) under the Ministry of Agriculture and Farmers' Welfare.

S. No	Name of the biopesticide	Target pests
1	*Ampliomyces quisqualis*	powdery mildews
2	*Bacillus subtilis*	Fungi
3.	*Bacillus thuriengensis var. israelensis*	Diptera particularly Mosquitoes, black flies, fungal knats
4	*Lysinibacillus sphaericus* (*Bacillus thuringiensis var. sphaericus)*	*Culex* and *Anopheles* mosquitoes
5.	*Bacillus thuriengensis var. kurastaki*	Lepidoptera insects
6	*Bacillus thuriengensis var. galleriae*	Coleoptera beetles
7	*Beauveria bassiana*	Termites, thrips, whiteflies, aphids and different beetles
8	*Hirsutella thompsonii*	Insects and Nematodes
9	*Metarhizium anisopliae*	Termites and thrips
10	*NPV of Helicoverpa armigera*	*Helicoverpa armigera*
11	*NPV of Spodoptera litura*	*Spodoptera litura*
12	*Paecilomyces lilacinus*	*Nematodes*
13	*Pseudomonas fluorescens*	Fungi and nematodes
14	*Trichoderma harizianum*	Fungi
15	*Trichoderma viridae*	Fungi
16	*Lecanicillium lecanii* (*Verticillium lecanii)*	whitefly, thrips and aphids,
17	*Verticillium chlamydosporium*	Nematophageous fungi,
18	*Grannulosis Viruses (GV)*	Insects
19	Gliocladium Species	Fungi
20	*Nomuraea rileyi*	Insects
21	Azadirachtin	200 pest species belonging to the major

		insect orders of Diptera, Hymenoptera, Coleoptera, Lepidoptera, Orthoptera, Homoptera and Hemiptera
22	Neem leaves, Neem oil, Neem seed kernel, Neem cake	Insects of Diptera, Hymenoptera, Coleoptera, Lepidoptera, Orthoptera, Homoptera and Hemiptera
23	Pyrethrins (Pyrethrum)	Ants, aphids, roaches, fleas, flies and ticks
24	Pheromone (ZZ/ZE-7, 11 Hexadecadien 1-yl acetate PB Rope-L)	Pink boll worm of cotton (*Pectinophora gossypiella*)
25	Triacontanol	Plant Growth Promoter
26	Spearmint (*Mentha Spicata*) Oil containing L-Carvon, Limonin and Pines	Mosquitoes, insects
27	American Wormseed Oil, (Chenopodium Oil)	Insects, mosquitoes, fungi
28	Karanjin (isolated from *Pongamia glabra*)	Mites



Market Overview of Biopesticides in India	
Study Period	2017-2030
Base Year of Estimation	2024
Forecast Data Period	2025-2030
Market Size (2025)	USD 242.16 Million
Market Size (2030)	USD 381.23 Million
Growth Rate (2025-2030)	9.5 % CGAR
Market Concentration	Low

Figure.2. Biopesticide Market in India (Source of data: courtesy of Mordor intelligence) [40]

Presently, in the Indian pesticide market, biopesticides encompasses a minor portion of entire crop fortification market which accounts for 5% [41] and is supposed to contribute up to 50% of the overall pesticide market by 2050 [42,43]. The global biopesticide market is also expected to match the size of the chemical pesticide market by 2050 [44]. Pest Control India, International Panaacea Ltd., T Stanes and Biotech International are the major organized players. Other companies dominating Indian market for their products, services and continuous product developments are Camson Bio Technologies Ltd., Sri Biotech Laboratories India Ltd., Valent Biosciences Corp., Eid Parry, etc. [45]. Due to their sincere efforts, the consumption of biopesticides increased from 219 tonnes in 1996–1997 to 683 tonnes in 2000–2001 [46,47] and over 6148 tonnes in 2015-2016 and 8,898.92 tonnes in

2021-2022[48]. Consumption is highest in states like Maharashtra, West Bengal, and Karnataka, which utilize the largest volumes of formulations such as *Trichoderma* and neem-based products. Rajasthan reported a nearly 100-fold increase in biopesticide use over a seven-year period, jumping from below 15 tonnes (pre-2019) to 1,268 tonnes in 2021–22. States like Uttar Pradesh and Andhra Pradesh report some of the lowest biopesticide consumption levels among large states, with Uttar Pradesh using less than 51 tonnes in 2021–22[48]. The pace of development of Indian biopesticide market is not very impressive. Its market can be only expanded with government's aid not only in monetary terms but also by the development of storage facilities at different level of supply chain, which require special training and skills.

4.Conclusion: Utilizing the developments in nanotechnology, molecular biology, and biotechnology, modern agricultural methods now enable the sustainable, in-plant manufacture of biopesticides. These bio-based products provide tailored pest control and have long been considered a safer, more ecologically friendly option to traditional chemical agents. New tools based on biological control agents (BCAs) and natural antimicrobial compounds for disease control can help realize the goal of having a clean and safe environment. Many Indian research labs are now concentrating and focussing on identifying microbes and antimicrobial botanicals that can either stop the growth of plant diseases or eradicate them.

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