Food and Agriculture Organization of the United Nations

Antibiotic use in horticulture and crop production in India

A REVIEW

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Abbreviations

AMR	antimicrobial resistance
CAGR	compound annual growth rate
CIBRC	Central Insecticide Board and Registration Committee
CSE	Centre for Science and Environment
DPPQS	Directorate of Plant Protection, Quarantine and Storage
FAO	Food and Agriculture Organization of the United Nations
FFSs	farmer field schools
FSSAI	Food Safety and Standards Authority of India
GoI	Government of India
GVA	gross value added
ICAR	Indian Council of Agricultural Research
INFAH	Indian Federation of Animal Health Companies
IPM	integrated pest management
KVKs	Krishi Vigyan Kendras
LMICs	low- and middle-income countries
MPEDA	Marine Products Export Development Authority
NPPO	National Plant Protection Organization
SLTPs	seasonal long training programmes

1. Introduction

The application of antibiotics in agriculture, particularly in horticulture and crop production and protection, has been a practice since the 1950s, primarily for managing bacterial diseases in high-value plantations and crops. Worldwide, up to 39 countries are reportedly using antibiotics such as kasugamycin, gentamicin, streptomycin, oxolinic acid, oxytetracycline, validamycin, or zhongshengmycin in agriculture. These antibiotics are largely used to control plant pathogenic bacteria, highlighting the global prevalence of this practice. In India, the use of antibiotics in horticulture, and crop production and protection may be a growing concern, potentially due to misuse, overuse or unintended use of these substances by farmers to combat bacterial diseases. The indiscriminate use can have significant implications for public health, particularly contributing to increasing antimicrobial resistance (AMR) and knock-on effects on plant, animal and human health.

This technical brief focuses on the use of antibiotics in horticulture and crop production sector in India, while highlighting the broader global context and perspectives on antibiotic use in this sector. It aims to examine the types of antibiotics used, the extent of their use, regulatory frameworks and considerations, and the potential implications for antibiotic resistance, environment, and public health. Additionally, the brief compares antibiotic use in horticulture and crop production with that in livestock, poultry, fisheries and aquaculture sectors, respectively. Finally, it provides actionable recommendations for reducing antibiotic use and mitigating its impacts, including the development of AMR, in the horticulture and crop production sector.

2. Common antibiotics used in horticulture and crop production and protection

2.1 International status

Globally,[1-3] the most commonly used antibiotics in horticulture and crop production and protection include:

- **Streptomycin:** This is the most widely utilized antibiotic in plant agriculture, and is particularly effective against bacterial diseases such as fire blight in apples and pears. In various crops it is frequently recommended, and is often used prophylactically.

- **Oxytetracycline:** It is commonly used alongside streptomycin, and is effective against a range of bacterial plant pathogens. Its application effectively manages bacterial spot in peaches and other crops.

- **Kasugamycin:** This antibiotic is primarily used in Asia, and is effective against specific plant bacterial diseases. Its use yet seems to be less widespread compared to streptomycin and oxytetracycline.

- **Oxolinic acid:** This antibiotic is mainly used in the Western Pacific, particularly against bacterial diseases in rice and other crops. Its application is not as common as the above mentioned antibiotics.

Other examples include gentamicin (reportedly used in some regions, particularly in Latin America, for managing a variety of bacterial diseases in crops) and tetracycline (used for its antibacterial properties in various crops). These antibiotics are often used in a mixed formulation with other pesticides, which can lead to concerns about the development of antibiotic-resistant or multi-resistant bacteria.

2.2 Indian status

In India,[1, 4, 5] the most commonly used antibiotics in horticulture and crop production and protection are:

- **Streptomycin:** This has been the most widely used antibiotic, often applied as a mixture called streptocycline along with another antibiotic, tetracycline. It is used to treat bacterial diseases in apples, beans, citrus fruits, and potato etc. On 17 December 2021, the Government of India (GoI) published a draft order[6] stating that with effect from 1 February 2022, no person shall import, manufacture or formulate streptocycline for use in agriculture in India. Further, the use of streptocycline shall be completely banned in agriculture with effect from 1 January 2024.

- **Kasugamycin:** This is used as a bactericide and fungicide in crops. It is used to combat the blast disease in rice (paddy), and early blight control in tomatoes.

- **Validamycin:** This is used as an antibiotic fungicide, to manage mainly sheath blight in rice.

- **Aureofungin:** This is used as an antibiotic fungicide to manage blast disease in rice, downy mildew disease in grapes, gummosis in citrus fruits, and blight in potatoes etc.

3. Extent of use and regional variations

The Food and Agriculture Organization of the United Nations (FAO) conveyed that presently, there is no robust global data[4] on the quantity of antimicrobials used as pesticides in plant production and protection. For instance, at least 20 nations have registered antibiotics to control fire blight and citrus greening disease in plants. Some parts of the world have allowed streptomycin to be used to control certain bacterial diseases occurring in crops. Antibiotic use in agriculture is estimated to range between 57 000 tonnes and 217 000 tonnes annually, according to global projections.[7] However, the precise share of antibiotics used specifically for crop production remains uncertain.[8]

In low- and middle-income countries (LMICs), the lack of monitoring and regulation complicates the assessment of antibiotic use, with some studies indicating that usage could be substantially higher than that in developed nations.[1] At the Centre for Science and Environment (CSE), India in 2019, a study highlighted that many farmers were unaware about streptocycline being a combination of antibiotics, and were using it routinely.[9, 10]

In India, monitoring and documentation of pesticides are done by the Directorate of Plant Protection, Quarantine and Storage (DPPQS), GoI (which is the National Plant Protection Organization [NPPO] of India). The data[11] obtained from the statistical database of the DPPQS is illustrated in Figure 1. It shows the annual usage (tonnes) of antibiotics as pesticides during the periods of 2018-19 to 2023-24. The annual use of these (yearly total) ranging between 20 and 37 tonnes per year, is limited compared to a total of more than 20 000 tonnes per year consumption of chemical pesticides, as reported by the DPPQS. This suggests that there is monitored use of antibiotics in horticulture and crop production in India.

In 2021, the GoI[6] announced a draft order on the phase-out and eventual ban of streptocycline from 1 January 2024, as continued use of these substances in agriculture may pose risk of development of resistance to these antibiotics (AMR transmission) in environment, human beings and animals. However, as of 7 March 2025, DPPQS conveyed that research studies conducted till date have not conclusively supported this claim. Currently, research bodies and GoI are undertaking further studies to test this claim and gather sufficient data for evidence-based decision-making regarding the phase-out/ban of streptocycline.

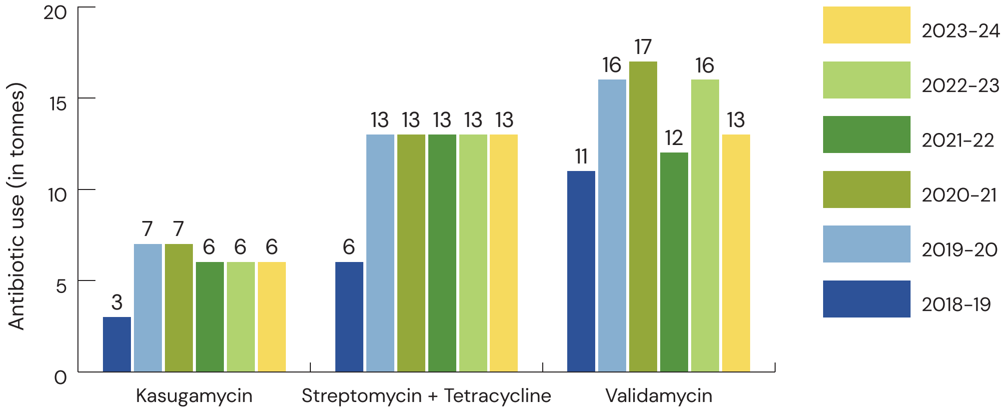

Figure 1: Usage of antibiotics as pesticides in India during 2018-19 to 2023-24.

Source: **DPPQS.** 2025. Statistical Database | Directorate of Plant Protection, Quarantine & Storage | GOI. [Cited 21 April 2025]. https://ppqs.gov.in/statistical-database

Worldwide, as such there are neither guidance nor methodology proposed to systematically collect data on antibiotics used as plant protection products, AMR of plant pathogenic bacteria or alternative and innovative treatments for the control of phytopathogenic bacteria. The report[12] by the European Food and Safety Authority on data collection on antibiotics for control of plant pathogenic bacteria, aims to reducing risk assessment uncertainties. It highlights the lack of publicly accessible data on antibiotics as plant protection products.

4. Regulatory considerations

The use of antibiotics in plant agriculture is subjected to regulatory scrutiny due to the potential for resistance to transfer to human pathogens, raising public health concerns, as can arise with any pesticides that are applied on field.

Regulatory frameworks governing antibiotic use in agriculture vary significantly across world regions. In the United States of America, the Environmental Protection Agency regulates the use of antibiotics in plant agriculture, while in Europe and west Africa, such uses are generally prohibited. The differing regulations reflect varying public health priorities, and the recognition of the potential risks associated with antibiotic use in crop production.[3, 13, 14]

In India, the Central Insecticide Board and Registration Committee (CIBRC) – regulates the use of pesticides including antibiotics, ensures compliance with safety standards, and works to prevent misuse or overuse that could lead to resistance or environmental harm. The CSE study[9, 10] in 2019, conveyed that the regulations' enforcement was not followed on ground in several farms in Delhi, Punjab and Haryana, and that there is a limited monitoring of antibiotic usage practices on farms. In March 2021, the GoI[15] stated that there is no indiscriminate use of antibiotics in food crops in about 17 states[a] of India. This suggested that the regulations may need further enforcement at the farm level in other remaining states of India with regular monitoring across all states pan-India.

Furthermore, some State Agriculture Universities in India run Krishi Vigyan Kendras (KVKs), which help farmers tackle agriculture-related issues as per the guidelines by the national research body, the Indian Council of Agricultural Research (ICAR).[9] The KVKs typically follow the ICAR guidelines. These may be different from CIBRC but are based on scientific evidence. While CIBRC focuses on the regulatory aspects of pesticide

a Namely, Himachal Pradesh, Rajasthan, Gujarat, Uttarakhand, Uttar Pradesh, Jharkhand, Odisha, Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Telangana, Karnataka, Kerala, Tamil Nadu, Goa and Nagaland registration and safety compliance, ICAR emphasizes research, education, and sustainable agricultural practices. Both organizations work together to ensure that pesticides are used effectively and responsibly in Indian agriculture.

For grassroot level regulations, the GoI has adopted integrated pest management (IPM) as key principle of plant protection in the overall crop production programme since 1985. Human resource development in IPM is done by imparting training to agriculture/horticulture extension officers and farmers by organizing farmer field schools (FFSs) and seasonal long training programmes (SLTPs) annually, essentially during *rabi* and *kharif* seasons. During 2023-24,[16] GoI conducted 206 FFSs in which about 7 210 farmers were trained, and two 30-day SLTPs were conducted in which 80 master trainers were trained.

5. Implications for antibiotic resistance

The use of antibiotics[1, 13, 17] in agriculture raises significant concerns regarding the development and spread of antibiotic resistance. Antibiotic resistance genes could be transferred from plant-associated bacteria to human pathogens, potentially exacerbating the public health crisis of antibiotic resistance and thereby AMR. Six of the eleven antibiotics commonly used in agriculture are classified by the World Health Organization as critically important for human medicine, raising concerns about their agricultural application. The timeline[8] of reported incidences of antibiotic-resistant plant-pathogenic bacteria around the world between 1991 and 2023, is given in Figure 2.

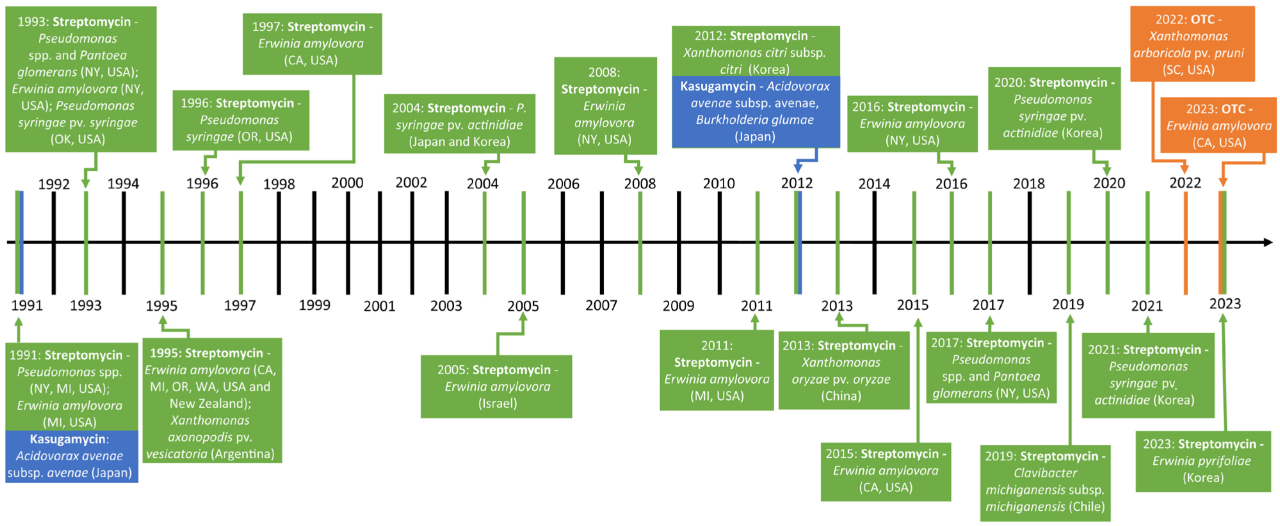

Figure 2: Timeline of reported incidences of antibiotic-resistant plant-pathogenic bacteria around the world between 1991 and 2023. Green indicates streptomycin resistance detected; orange represents oxytetracycline resistance detected; blue represents kasugamycin resistance detected.

Source: **Batuman, O., Britt-Ugartemendia, K., Kunwar, S., Yilmaz, S., Fessler, L., Redondo, A., Chumachenko, K., Chakravarty, S. & Wade, T.** 2024. The Use and Impact of Antibiotics in Plant Agriculture: A Review. Phytopathology®, 114(5): 885 – 909. https://doi.org/10.1094/PHYTO-10-23-0357-IA

6. Environmental implications

The use of antibiotics in horticulture and crop production haves significant environmental implications, [4,18-20] primarily due to their effects on microbial communities in ecosystems, the development of antibiotic resistance thereby contributing to AMR, and contamination of soil and water systems. Antibiotics may enter the environment primarily through agricultural runoff, leaching from treated soils, and the application of contaminated manure as fertilizer. Animal waste containing antibiotic residues can contaminate surrounding soil and water sources when used in agriculture.

In India, antimicrobial-resistant bacteria and their genes have been reported from different water sources pan India. The major sources reportedly are pharmaceutical waste waters and hospital effluents that are released into the nearby water bodies without adequate treatment. Other key drivers for environmental AMR include contributions by biocides (including insecticides, pesticides, fertilizers and disinfectants). Sub-lethal concentrations of biocides can increase the pool of resistant organisms in the environment. However, there is no data available on biocides including antibiotic residues in environmental ecosystems, and this warrants monitoring and surveillance at national level.

The integrity of natural ecosystems encompassing soil and water systems is potentially threatened due to presence of antimicrobials from industrial and agricultural runoff. Environmental implications of antibiotics are profound, affecting soil health, water quality, microbial diversity, and public health through the development of antibiotic resistance.

7. Public health implications

Issues regarding the impact of agricultural-antibiotic use on human health[8, 19, 21, 22] have been raised, particularly about the potential transfer of resistance genes from plant-associated bacteria to human pathogens. However, no direct evidence has linked agricultural antibiotic use to adverse human health outcomes, and significant residues on harvested crops have not been detected. Bacteria, particularly zoonotic organisms with resistance to one or more antibiotics, are found on fruits, vegetables, cereals, other edible plants, and in soils. The frequency with which plant-origin resistant bacteria colonize the human gastrointestinal tract and serve as reservoirs of AMR genes in the gastrointestinal tract needs to be ascertained.

Though human exposure to antibiotics through diet remains insufficiently studied, there is a concern pertaining to the potential presence of antibiotic residues on crops and their implications for consumer health. This is particularly critical for fruits such as apples and pears, which are often consumed raw. The presence of residues poses a potential public health risk, emphasizing the importance of further research into dietary exposure pathways and mitigation strategies.

8. Antibiotic use in livestock, poultry, fisheries and aquaculture sectors

8.1. Livestock and poultry

Antimicrobial use in food animal production is a growing concern worldwide. In 2017, global antimicrobial sales for chicken, cattle, and pig production in 41 countries were estimated at 93 309 tonnes, with projections indicating a rise of 11.5 percent by 2030, reaching 104 079 tonnes.[23] Global antimicrobial consumption in food animal production is expected to increase by 67 percent by 2030. In 2017, the top[23] five veterinary antimicrobial consumers were China (45.0 percent), Brazil (7.9 percent), US (7.0 percent), Thailand (4.2 percent), and India (2.2 percent). Extrapolations from high-income countries to low-income countries indicate that global antimicrobial consumption in food animal production was about 63 151 tonnes in 2010, and is projected to increase by 67 percent to around 105 596 tonnes by 2030. This increase is driven primarily by two factors namely, (i) growing livestock populations account for 66 percent of the projected rise, and (ii) a possible shift toward intensive farming systems, where antimicrobial use is more prevalent, accounts for the remaining 34 percent.[24]

According to the Twentieth Livestock Census[25] (2019), India has a vast and diverse livestock population, including 302.79 million bovines, 74.26 million sheep, 148.88 million goats, 9.06 million pigs, and approximately 851.81 million poultry. The livestock sector in India has been growing steadily, with a compound annual growth rate (CAGR) of 7.93 percent. India's animal husbandry sector plays a critical role in the national economy, contributing 5.73 percent to the total gross value added (GVA) in 2021 – 22 and 30.19 percent to the agriculture and allied sector GVA. Despite impressive growth of the sector, healthcare challenges, including inadequate infrastructure and disease management, remain significant. Antibiotics are essential in treating infectious diseases and ensuring animal health, yet their use raises concerns about AMR. Given these trends, addressing antimicrobial use in livestock production is crucial to mitigating risks associated with AMR while ensuring sustainable animal husbandry practices.

The data[26] obtained from the Indian Federation of Animal Health Companies (INFAH) is illustrated in Figure 3. It shows the annual usage (in tonnes) of antibiotics during the periods of 2019-20 to 2022-23. The annual use of these (yearly total) range between 912 and 1 042 tonnes. From 2019 to 2022, the estimated total antibiotic consumption in the sector ranged from 912 tonnes in 2019-20 to 1 042 tonnes in 2021-22. A slight decrease was observed in 2022-23, with the total usage dropping to 998 tonnes. During 2021-22, there was a surge of antibiotic use in livestock due to epidemic outbreak of lumpy skin disease in cattle and buffaloes across India.

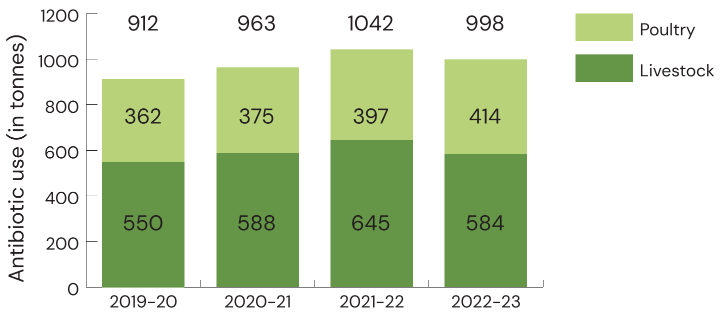

Figure 3: Usage of antibiotics in India during 2019-20 to 2022-23 in livestock and poultry.

Source: **INFAH.** 2023. Antimicrobial Usage in Indian Animal Healthcare during 2022-23 - A Report

Certain classes[26] of antibiotics dominate the Indian veterinary market, reflecting their efficacy and cost-effectiveness such as tetracyclines (constituting up to 40 percent of the veterinary antibiotic market, and widely used due to their broad-spectrum activity), fluoroquinolones, macrolides and aminoglycosides, sulfonamides and trimethoprim combinations. The rising antimicrobial usage in India reflects the dual challenge of meeting the demands of a growing livestock population while managing the risk of AMR.

8.2 Fisheries and aquaculture

Global antimicrobial consumption[27] in aquaculture in 2017 was estimated at 10 259 tonnes. From this baseline, global antimicrobial consumption is projected to rise 33 percent to 13 600 tonnes by 2030. The Asia – Pacific region[27] accounts for the overwhelming majority (93.8 percent) of global consumption, and this percentage is projected to remain stable throughout 2017 – 2030. These statistics highlight the role of antibiotics in aquaculture and the challenges associated with their use, including the risk of AMR and environmental impact. In 2017, China accounted for approximately 57.9 percent of global antimicrobial consumption in aquaculture, with a projected decrease to 55.9 percent by 2030, and India was about 11.3 percent of global antimicrobial consumption, with this share expected to remain unchanged by 2030. Indonesia represents 8.6 percent of global antimicrobial consumption, with a projected increase to 10.1 percent by 2030, and Viet Nam accounts for about 5 percent of global antimicrobial consumption, with a projected increase to 5.2 percent by 2030.

India is one of the largest fish producing countries in the world and shares 7.58 percent to the global production. In 2018-19, fisheries and aquaculture sector contributed 1.24 percent to India's national GVA and 7.28 percent to the agricultural GVA.[28] India's seafood exports[29] touched an all-time high in volume during 2023-24 despite various challenges in significant export markets. India shipped 1 781 602 tonnes of seafood worth INR 60 523.89 crore (USD 7.38 billion) during 2023-24. The aquaculture sector has contributed 62 percent of exported items in terms of USD and 38 percent in terms of quantity in 2023-24.

Approved antibiotics for use in the fisheries and aquaculture sector vary by country.[30] For instance, in the US, approved antibiotics for this sector include oxytetracycline, florfenicol, etc. The use of antibiotics is heavily restricted, requiring approval of the US Food and Drug Administration (FDA) and veterinary supervision. Other countries like China and Viet Nam have some classes of approved antibiotics as well.

In India, there are no antibiotics specifically approved[30, 31] for use in aquaculture. However, several antibiotics are commonly used despite not being officially approved for aquatic animals. These include enrofloxacin, oxytetracycline, cephalexin, doxycycline, and erythromycin. Many antibiotics used in aquaculture are classified as Schedule H drugs, which are prescription drugs but are often sold over the counter to farmers. While not specifically approved for aquaculture, some medications like florfenicol, flumequine, and oxolinic acid, are used in aquaculture practices as well.

The Food Safety and Standards Authority of India (FSSAI) has set tolerance limits[32] for antibiotics like tetracycline, trimethoprim, oxytetracycline, and oxolinic acid in seafood intended for human consumption. The Marine Products Export Development Authority (MPEDA) monitors[30] seafood for antibiotic residues, primarily for international trade. In states like Maharashtra,[33] district-level committees and task forces were established to monitor and curb the use of banned antibiotics in aquaculture.

The annual usage of antibiotics during the periods of 2019-20 to 2022-23, in tonnes, is given in Figure 4. The data revealed that the livestock and poultry sector have annual antibiotic utilization of more than 25 times than that of horticulture and crop production sector in India in any given year during the reported period.

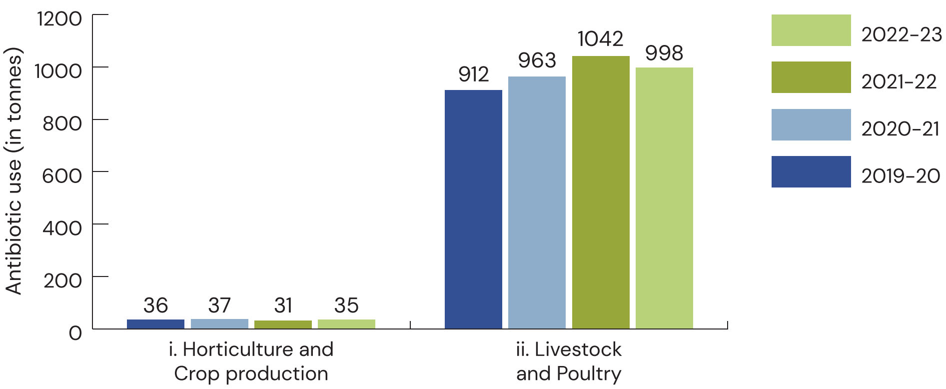

Figure 4: Usage of antibiotics in India in i. Horticulture and crop production, and ii. Livestock and poultry during 2019-20 to 2022-23.

Sources: **DPPQS.** 2025. Statistical Database | Directorate of Plant Protection, Quarantine & Storage | GOI. [Cited 21 April 2025]. https://ppqs.gov.in/statistical-database;

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9. Recommendations

Given the growing concerns over AMR and the critical need to preserve antibiotic efficacy for both human and agricultural health, it is imperative to implement evidence-based strategies that promote responsible antibiotic use and sustainable disease management in agricultural systems.[8] Key recommendations[4, 12, 34] are:

9.1 Strengthen national regulatory mechanisms pan-India to prevent misuse or overuse of antibiotics at farm level.

9.2 Strengthen monitoring and surveillance initiatives viz. on the use and the sales of antibiotics in horticulture and crop production, the area where they are applied and on which crops, and for antibiotic residues and antibiotic resistance on plant protection products.

9.3 Conduct regular surveys and studies on the environmental and health impacts of antibiotic use in farming.

9.4 Reduce need for antimicrobials in plant production

- Prevention of plant diseases: Plant disease prevention by natural means such as improving farm sanitation, applying crop rotation, managing soil health, mulching, judicious watering, pruning and spacing, fallowing, biological controls, and regular monitoring of plants for disease prevention.
- Promote good practices: Implementation of good agricultural and production practices, biosecurity, and infection control.
- Strengthen IPM, which recommends the use of pesticides as a last resort when all other practices to control the disease have failed. IPM provides sustainable pathways for plant diseases control which include the following but not limited to:
  - » Accurate diagnosis and monitoring through identification of plant diseases and utilizing tools such as disease modelling and predictive systems to optimize the timing of pesticide applications.
  - » Breeding of disease resistant crop varieties and rootstocks, which is a long term and sustainable solution. It is applicable to both fruit systems, and annual crops and vegetable systems.
  - » Exclusionary measures such as planting pathogen-free seeds, using clean irrigation water, and adhering to sanitation practices prevent pathogen introduction and spread between plants and fields.
  - » Choosing suitable planting sites and enhancing soil health help maximize plant resilience and reduce conditions that favour pathogens. Rotating crops and adopting specific farming techniques can prevent the buildup of pathogens in the soil. Using eco-friendly biological solutions supports sustainable disease management.

9.5 Raise awareness on the risk of improper use of antibiotics as plant protection products and about the implications of AMR arising from agricultural use, among all stakeholders, including farmers, policymakers, consumers and public.

9.6 Capacity building trainings for farmers and other stakeholders on responsible application of antimicrobial-associated pesticides and educating them on the consequences of irresponsible use.

9.7 Allocate funding for research into alternative pest management strategies that reduce reliance on chemical treatments, including antibiotics. Such as in areas of:

- Applying nature-based solutions with effective biological agents, leveraging the microbiome and soil health to naturally control plant diseases such as using biopesticides etc.
- Selective breeding to decrease host plant's susceptibility to diseases.
- Discovering bactericides with unique modes of action distinct from those used in human and veterinary medicine.

9.8 Increase partnerships and collaboration between agricultural, health, and environmental sectors. This is essential to develop a One Health approach for addressing antibiotic use and its impact on AMR.

9.9 Prevention of bacterial contamination: Reduce or eliminate bacteria or AMR genes from fruits and vegetables, which are consumed raw or with minimal processing. Prevention of contamination, at all stages of production and processing, is of paramount importance to reduce the introduction of AMR organisms into the plant-based food chain.

- The development, validation, and application of additional contamination prevention strategies along the entire food chain could greatly reduce AMR development in plant-based foods.

9.10 Dispose unused/expired antimicrobials and containers safely: Buy antimicrobials only when needed, and do not stockpile them. Leftover or expired pesticides and pesticide containers should be disposed according to local administration's policy and guidelines, such as returning them to vendors or taking them to hazardous waste treatment facilities.

10. Conclusion

The management of bacterial diseases in horticulture and crop production and protection involves use of antibiotics; however, their use should be judiciously managed to mitigate potential risks. While the overall use of antibiotics in agriculture is modest compared to livestock, poultry, fisheries and aquaculture sectors,[3, 22, 24, 27] the potential for AMR development necessitates improved monitoring and regulation.

Developing suitable alternatives to antibiotics in managing plant pathogenic bacteria is increasingly important due to concerns over antibiotic resistance and environmental impacts. Suitable alternative strategies[12] encompass bacteriophages, biocontrol agents, plant extracts/ natural compounds, competitive exclusion, IPM and improved agricultural practices (such as crop rotation, soil health management, and proper irrigation) that can reduce disease pressure. These strategies help mitigate the risks associated with antibiotic resistance, promote healthier ecosystems and safer food production practices. Sustained research and investment in these alternatives will be essential for effective disease management in horticulture and crop production.

Furthermore, continued research is crucial to understand the full impact of antibiotic use in horticulture and crop production and protection on public health in a One Health perspective. There is a need for improved regulatory mechanisms, reducing the use of antibiotics in horticulture and crop production such as by above mentioned alternatives, farmers' and key stakeholders' capacity building and education on the appropriate use of antibiotics, developing surveillance initiatives on antibiotic use and residues monitoring, and allocating funding for research into alternative disease management strategies that reduce reliance on chemical treatments, including antibiotics. Enhanced monitoring and research efforts into the scale of antibiotic use in Indian agriculture are essential to mitigate the risks associated with this practice.

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