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HOW TO USE

antimicrobials effectively and responsibly in

PLANT PRODUCTION,

for the sake of human and plant health



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Key messages

About antimicrobial resistance

- Antimicrobials are medicines used to prevent and treat infections in humans, animals and plants. They include antibiotics, antivirals, antifungals and antiparasitics.
- Antimicrobial resistance (AMR) refers to the ability of microorganisms to persist or grow in the presence of antimicrobials designed to inhibit or kill them. It occurs when bacteria, viruses, fungi or parasites change and no longer respond to medicines, making infections increasingly difficult or impossible to treat.
- Inappropriate use or improper disposal of antimicrobials may contaminate the environment, create food safety hazards and lead to the development of resistance.
- Antimicrobial residues above the acceptable limits may persist in food. This can make the food unsafe for human consumption – may be toxic, cause allergic reactions or induce cancer among consumers.

What can you do?

- Reduce the need for antimicrobials by adopting integrated pest management (IPM) to prevent plant pests and diseases.
- Manage plant diseases with minimal antimicrobials.
- Follow antimicrobial label instructions and guidance precisely.
- Dispose unused antimicrobials and their containers safely to minimize environmental contamination and risk to humans and animals.

Introduction to antimicrobial stewardship

Antimicrobials are chemical compounds used to treat diseases caused by microorganisms such as bacteria, viruses and fungi (FAO, 2023). Prudent, rational and targeted use of antimicrobials in plant production maximizes their therapeutic efficacy while reducing the risk of development of resistance and environmental contamination, improving food safety (FAO and WHO, 2005), and subsequently increasing profits due to minimal plant losses.

Antimicrobial resistance is a problem in plant production that leads to treatment failures, decreased crop yields and food safety hazards. Treatment failure prolongs the disease, leading to crop losses, lowered produce quality, and additional costs associated either additional or alternative treatments. Antimicrobial resistance can develop whenever antimicrobials are used. It develops more quickly when antimicrobials are not used properly. For instance, if they are used to treat nutritional deficiencies, infections that are not susceptible to the antimicrobial, at an incorrect dose or on a prolonged basis.

Many of the antimicrobials used in horticulture have identical or very similar chemical structure as medicines used to treat human and animal diseases (Miller et al., 2022). Thus, when applied in the field, these pesticides can also select for resistant strains of microorganisms present in the environment that do not impact plant health, but can cause serious diseases in humans and animals, making infections acquired from foods and the environment difficult to treat. Resistant microorganisms can spread to humans and animals from plants and the environment (see **Figure 1**).

Use of antimicrobials without observing the recommended withdrawal period between application and harvest may result in presence of chemical residues in the food above acceptable limits that makes the food unsafe for human consumption. Effects may be toxic, cancer-inducing, or, in some cases, result in allergic reactions among consumers, including life-threatening anaphylaxis (Arsène et al., 2022). Products with residues above acceptable limits may be rejected for trade, leading to economic losses (Codex Pesticides Residues in Food Online Database).

Herein we outline the components of antimicrobial stewardship in plant production.

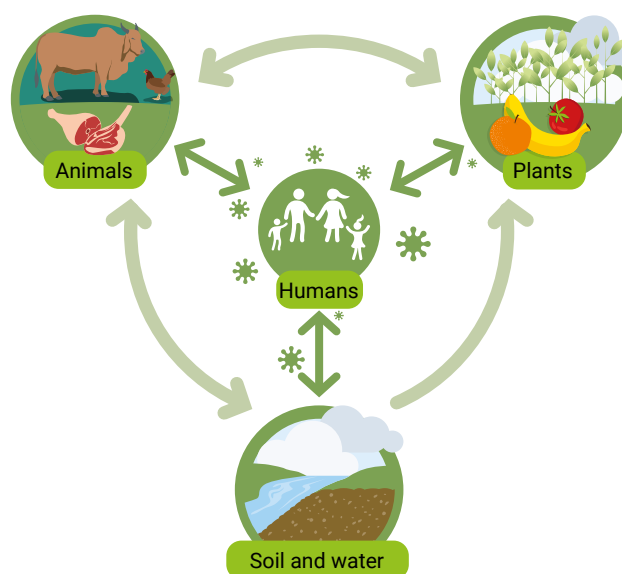


Figure 1. Humans and animals can get exposed to resistant microorganisms through 1) plant products; ii) environment (soil and/or water); and iii) direct contact with animals and animal products. Animals may also contaminate water, soil, and plants through faecal matter.

Benefits of antimicrobial stewardship

Prudent use of antimicrobials in plant production improves plant and environmental health leading to improved food safety and consumer health (see **Figure 2**).

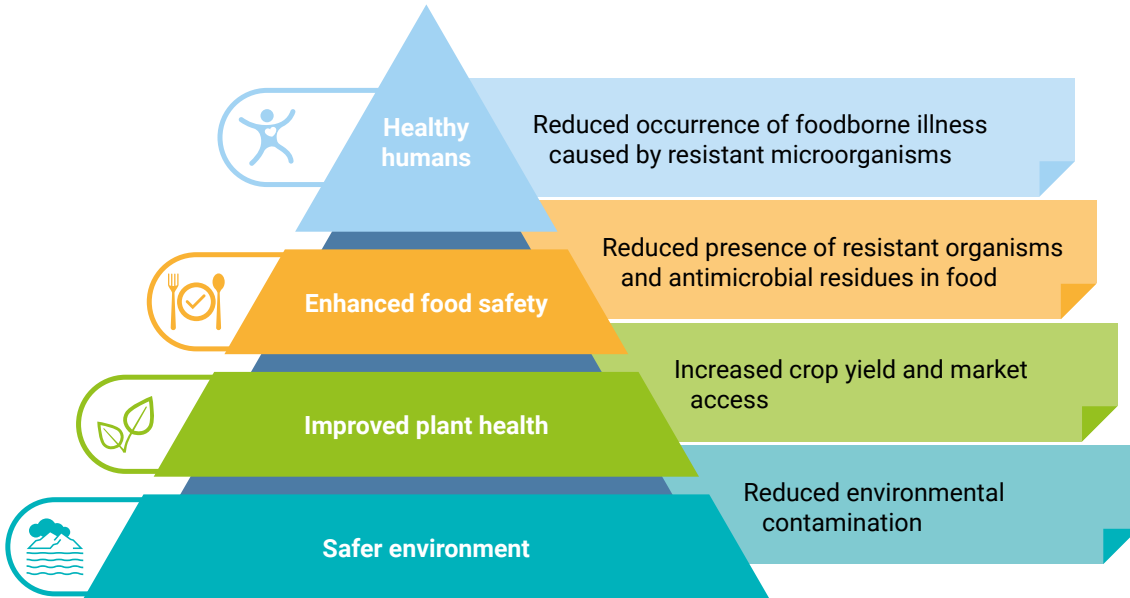


Figure 2. Benefits of antimicrobial stewardship in plant production.

How to achieve antimicrobial stewardship in plant production

Antimicrobial stewardship in plant production can be viewed as including the principles below (see **Figure 3**).

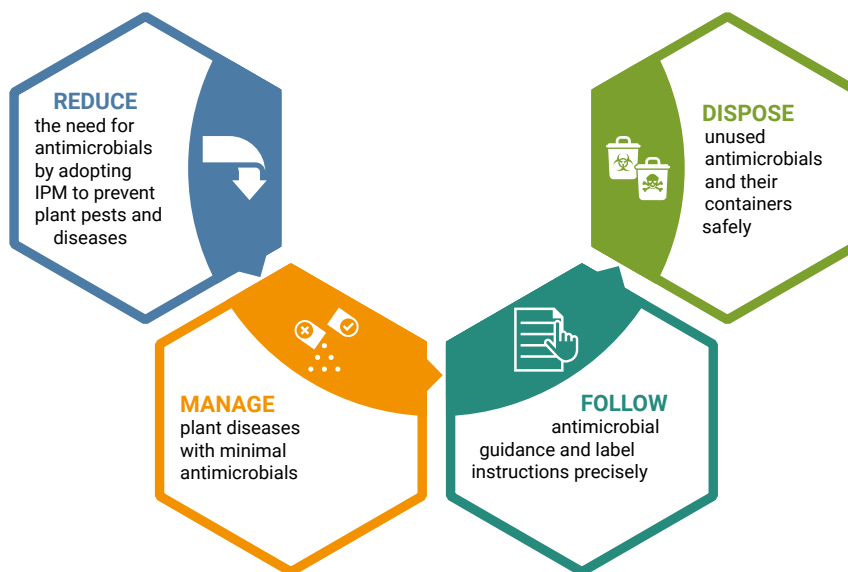


Figure 3. Four principles on which antimicrobial stewardship in plant production may be based.

1. Reduce the need for antimicrobials in plant production

Focus on prevention of plant diseases

Preventing plant diseases by adopting Integrated Pest Management (IPM) (see **Figure 4**) improves plant health, reduces disease incidence, and minimizes the need for antimicrobials in crop production (DAERA, 2017). Specific IPM measures include but are not restricted to:

- Use disease-resistant crop varieties, including disease-resistant rootstocks in both fruit and vegetable systems.
- Consider crop rotation and intercropping strategies such as push-pull technology that repel pests.
- Adopt practices that prevent introduction of pathogens into the farm, such as use of pathogen-free seed and vegetative planting material.
- Prevent the movement of pathogens from plant-to-plant or field-to-field. Be sure to clean and sanitize equipment after contact with infected crops. Sanitize the soil and irrigation systems.

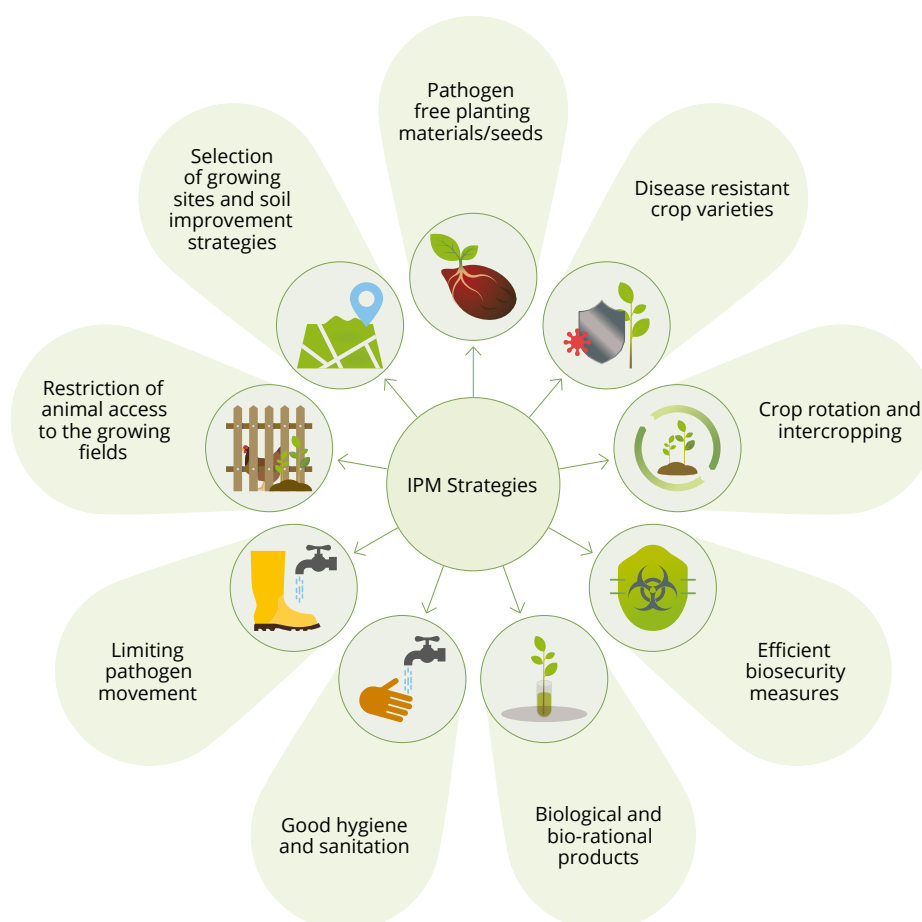


Figure 4. IPM integrates preventive and corrective measures to control pests and diseases, with minimum health risk to humans, animals and the environment.

- Deter rodents, wild birds and other wildlife and livestock from accessing the growing fields as they have been reported to introduce infectious agents as well as drug-resistant microorganisms into farms. Keep insects out with a double door system and appropriately sized meshed netting. Removal of rubbish and clutter from around production sites discourages animal habitats. Do not plant crops near dump areas as birds and rodents are attracted to such areas.
- Follow biosecurity measures such as cleaning or changing footwear when entering fields, especially after visiting markets or diseased farms.
- Select growing sites carefully and consider soil-improving strategies to maximize plant health and minimize environmental factors that favour persistence of pathogens.

2. Manage plant disease with minimal antimicrobials

Avoid unnecessary use

Use antimicrobials only when it is necessary and justifiable as recommended by a plant health professional, and no other treatment is available. All use of antimicrobials promotes emergence of resistance. Inappropriate use hastens this process and adds unnecessary costs at no added benefit. Where safer alternatives to antimicrobial use are available, choose them, for instance, stamping out or uprooting diseased crops to prevent further spread of disease to unaffected crops. Avoid blanket treatment and practise targeted treatment where only affected crops are treated.

Use the correct antimicrobial

Antimicrobials are developed to treat specific group of diseases. For instance, fungicides will not work on bacterial infections (e.g. infections caused by *Erwinia* spp., phytoplasmas). Likewise, antibiotics, like tetracycline and streptomycin, do not treat fungal diseases (e.g. rusts, wilts, botrytis) or viral diseases (e.g. Johnson grass mosaic virus). An incorrect diagnosis coupled with the wrong treatment is a recipe for failure and greater loss. Do not use unapproved antimicrobials.

Obtain accurate and timely diagnosis

Even to the trained eye, many plant diseases may look similar at first glance. It is important to seek guidance from a plant health expert when considering the use of antimicrobials. Accurate, timely diagnosis and treatment of plant diseases prevents spread of the infection. Proper diagnosis directs appropriate treatment protocols (see **Figure 5**).

3. Follow antimicrobial use directions carefully

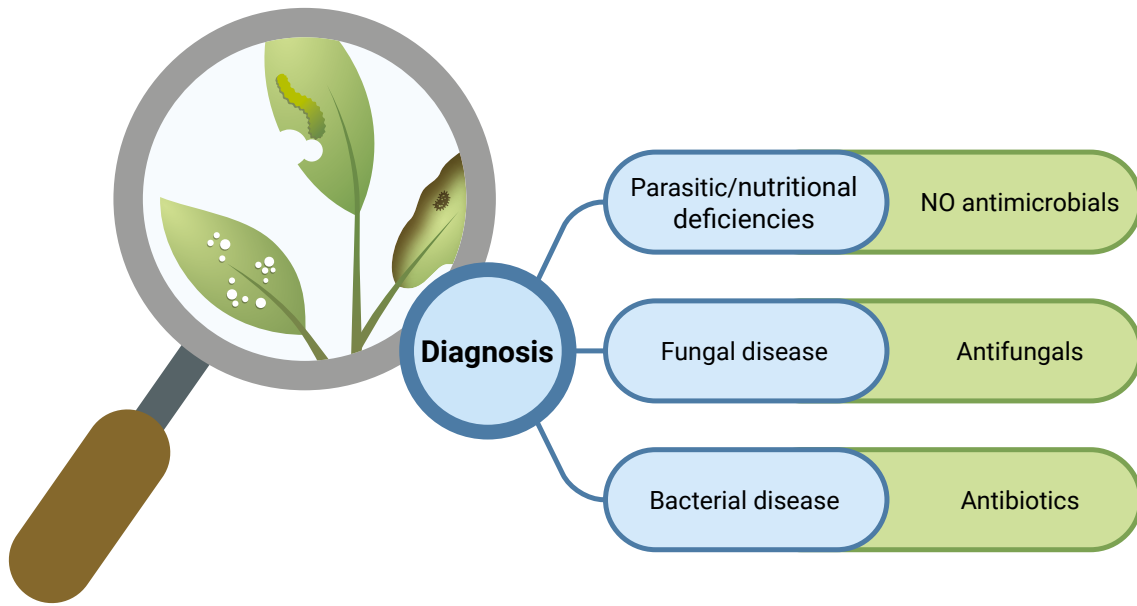


Figure 5. Accurate and timely diagnosis and treatment of plant diseases prevent further spread and minimize crop losses. Only use the correct type of antimicrobial for the specific disease being treated. Parasitic diseases and nutritional deficiencies do not respond to treatment with antimicrobials.

Adhere to correct dose and timing

Antimicrobials are optimized for a particular disease, at a given dose and for a specific duration. Antimicrobial labels and plant health professionals provide you with the correct dosage, length of treatment and appropriate mode of application of the antimicrobial for your particular problem. Purchase antimicrobials from reputable sources: Falsified and substandard pesticides may not work effectively (Newton et al., 2010). Purchase antimicrobials from reputable sources. Unlabelled or open products may be substandard or falsified, leading to treatment failure, and contributing to the development of antimicrobial resistance. Directions for use are available on the antimicrobial bottle provided by the manufacturer (see **Figure 6**).

If not used in accordance with label recommendations, the treatment may not be effective. For example, diluting a product to stretch or extend its volume can result in under-dosing, resulting in both treatment failure and accelerating the development of resistance. Do not use antimicrobials that have not been approved for the disease or crop you are treating.

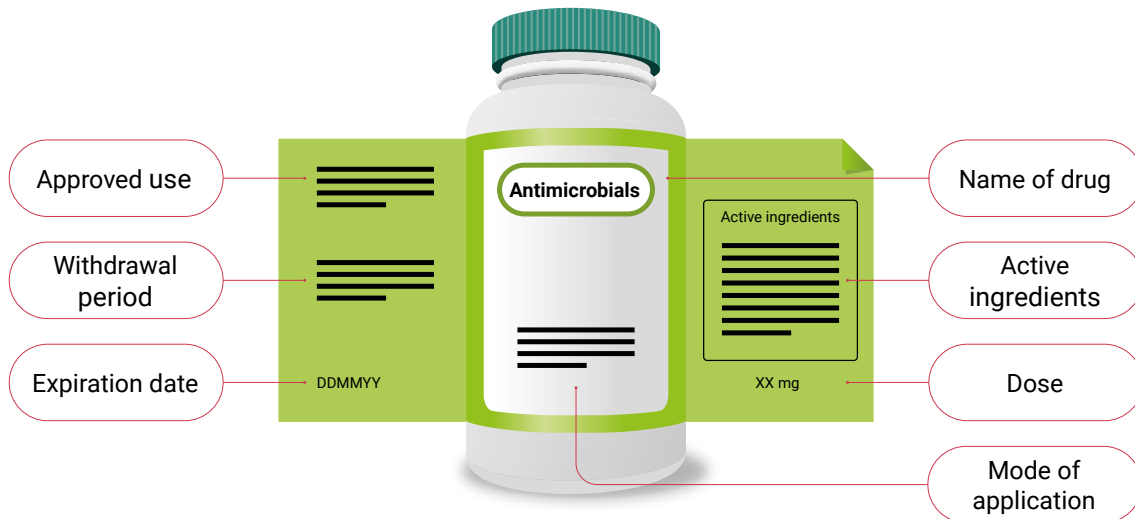


Figure 6. Labels on antimicrobials containers provide instructions for use.

On the other hand, higher than recommended doses of treatment do not necessarily make the pesticides work better or faster. Applying too much antimicrobial can be detrimental to plant health, result in excessive environmental contamination, dangerous residues and higher costs.

Keep records

It is important to record antimicrobial use. If plants fail to respond to an appropriate treatment, report to a plant health expert so that the treatment regime can be changed accordingly.

Wear personal protective equipment

When using antimicrobials and other pesticides, care should be taken to avoid exposure to the skin, clothes or inhaling or getting the products in the eyes (FAO and WHO, 2020). Wearing appropriate personal protective equipment (PPE) such as boots, lab coats, arm-length gloves and masks during application can provide protection. Remove the protective equipment when returning home so as not to expose your family, especially children, to pesticides on the clothing.

4. Dispose unused/expired antimicrobials and containers safely

Buy antimicrobials only when needed and do not stockpile them. Check the “use before” date prior to purchase and use. Old and expired antimicrobials may lose their potency and not work.

Leftover and outdated pesticide and pesticides containers should be collected and disposed of according to your local administration's policy and guidelines, such as returning them to vendors or taking them to hazardous waste treatment facilities (see **Figure 7**).

Dos	Don'ts
These actions minimize environmental contamination and the risk of toxicity to humans and animals.	These actions can lead to the contamination of soils and waterways, allowing for resistance development in the environment and direct toxic risk to humans and animal.
 Follow your local administration's policy and guidelines on disposal	Do not dispose of pesticides and containers in the environment 
 Drop off at the vendor	Do not put antimicrobials and containers in your household waste 
 Drop off at a hazardous waste treatment facility	Do not pour antimicrobials down the sink or toilet 
 Incinerate in a controlled environment	Do not reuse pesticide containers to collect or transport drinking water 

Figure 7. How to dispose of unused antimicrobials and containers.

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Contact information

When in doubt about what to do, please contact your national regulatory authority such as the ministry of agriculture for further guidance.

You can also contact the Food and Agricultural Organization of the United Nations (FAO) for any inquiries (Email: food-quality@fao.org).