



Food and Agriculture
Organization of the
United Nations

PRODUCTION PRACTICES TO INCREASE YIELD, QUALITY AND SAFETY OF FRUITS AND VEGETABLES



Acknowledgements

This document was developed through a one health collaborative approach between the Food Systems and Food Safety Division (ESF) and the Plant Production and Protection Division (NSP) and is anchored within FAO's Programme Priority Area (PPA) on One Health. Special thanks to Sally Miller, Kenneth Shenge, and Philip Taylor who provided technical input and insight during development of this document. FAO Contributors: Buyung Hadi, Emmah Kwoba, Jeffrey LeJeune, Fenton Beed, Jorge Pinto Ferreira and KimAnh Tempelman.

Required citation

FAO. 2024. Production practices to increase yield, quality and safety of fruits and vegetables. Rome. <https://doi.org/10.4060/cd0726en>

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO in preference to others of a similar nature that are not mentioned.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

© FAO and WHO, 2024



Some rights reserved. This work is made available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; <https://creativecommons.org/licenses/by-nc-sa/3.0/igo/legalcode>).

Under the terms of this licence, this work may be copied, redistributed and adapted for non-commercial purposes, provided that the work is appropriately cited. In any use of this work, there should be no suggestion that FAO endorses any specific organization, products or services. The use of the FAO logo is not permitted. If the work is adapted, then it must be licensed under the same or equivalent Creative Commons licence. If a translation of this work is created, it must include the following disclaimer along with the required citation: "This translation was not created by the Food and Agriculture Organization of the United Nations (FAO). FAO is not responsible for the content or accuracy of this translation. The original English edition shall be the authoritative edition."

Disputes arising under the licence that cannot be settled amicably will be resolved by mediation and arbitration as described in Article 8 of the licence except as otherwise provided herein. The applicable mediation rules will be the mediation rules of the World Intellectual Property Organization <http://www.wipo.int/amc/en/mediation/rules> and any arbitration will be conducted in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL).

Third-party materials. Users wishing to reuse material from this work that is attributed to a third party, such as tables, figures or images, are responsible for determining whether permission is needed for that reuse and for obtaining permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

Sales, rights and licensing. FAO information products are available on the FAO website (www.fao.org/publications) and can be purchased through publications-sales@fao.org. Requests for commercial use should be submitted via: www.fao.org/contact-us/licence-request. Queries regarding rights and licensing should be submitted to: copyright@fao.org.

Layout: Lowil Fred Espada

Contents

Background
5

**Benefits of
adopting good
agricultural
practices (GAP)
in horticulture**
6

**Six good agricultural
practices to increase
crop yield, quality and
safety of fruits and
vegetables**
6

- 1/ Prevent plant pests and diseases through integrated pest management (IPM) 7
- 2/ Use water that is fit for purpose 9
- 3/ Treat soil amendments to reduce microbial contaminates 9
- 4/ Ensure farm equipment and containers are clean and dry 10
- 5/ Keep animals away from fields and packing facilities 10
- 6/ Practice good hygiene, sanitation, and biosecurity 11

Conclusion
12

References
12



Background

Healthy plants lead to increased productivity and profitability. In addition, fruits and vegetables produced from healthy plants may be more attractive to buyers and have a longer shelf life, contain higher vitamin and mineral content, and have less microbial and chemical contamination — factors making them safer, more nutritious for consumption, and potentially increasing market value and access.

Bacteria, viruses, fungi, and protozoa can contaminate plants at any stage of production, from primary production, through the stages of harvest and post-harvest storage. Microorganisms in soil are important in maintaining soil fertility and texture. However, many of these microorganisms can cause plant disease and subsequent production losses and decrease in quality, while other organisms originating from irrigation water, manures, farm workers or equipment can cause diseases in people. These human disease-causing microorganisms can survive on the surface of fruits and vegetables under favorable conditions. This poses a threat to human health because fruits and vegetables are often eaten raw or with minimal cooking. Viral pathogens, such as noroviruses, and bacterial agents such as *Salmonella* spp, *Listeria monocytogenes* and *Escherichia coli* have been responsible for many foodborne outbreaks involving fruits and vegetables globally (Yangjin et al, 2014).

Pesticides including antimicrobials are used to treat plant pests and diseases. If treated crops are harvested without observing the recommended withdrawal period, pesticides and antimicrobial residues persisting on food products can cause serious harm to human health. More importantly, the use of antimicrobials leads to development of resistance which renders them ineffective, consequently leading to crop losses due to treatment failure and increased cost of controlling prolonged diseases. The antimicrobial resistance driven by antimicrobial use in plant production may be transferred to microorganisms present in the environment, making them resistant to antimicrobials too, contaminating food products, and infecting people through the food chain.

Preventing plant pests and diseases through good production practices boosts plant health, increases yields, enhances quality and improves food safety. Here we describe six good agricultural practices (GAP) to simultaneously achieve these goals.

Benefits of adopting good agricultural practices (GAP) in horticulture

Adopting good production practices in horticulture has multiple benefits.

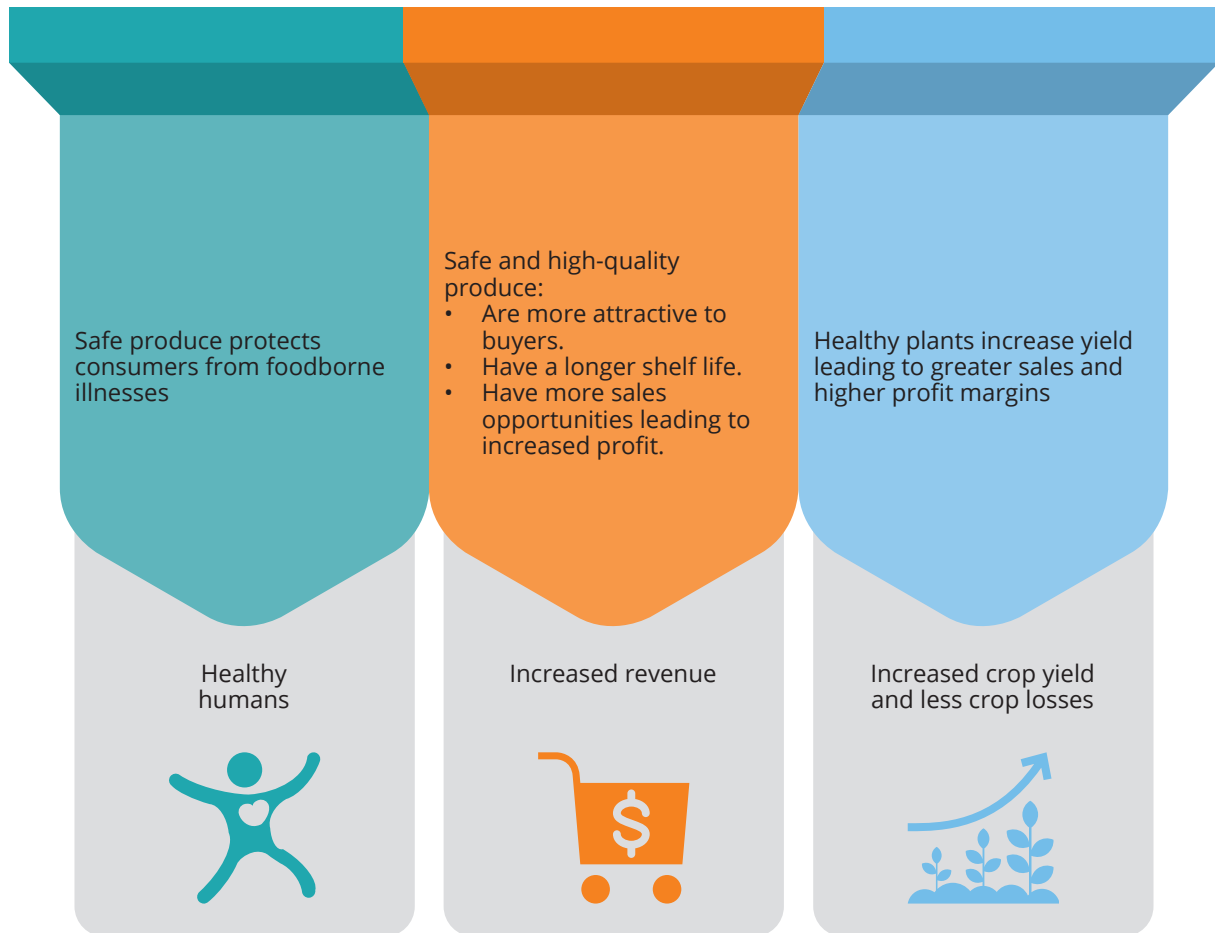


Figure 1. Three benefits of adopting GAP in horticulture.

Six good agricultural practices to increase crop yield, quality and safety of fruits and vegetables

If adhered to, the following six practices will enhance the quality and safety of the produce as well as increase yield.



Figure 2. Six good production practices to enhance quality, quantity, and safety.



When plant pests such as bacteria and fungi significantly infect a field, they damage and destroy plants, lead to reduced crop yield due to wastage, lowered quality, and compromised safety of the product. Preventing plant pests and diseases through good plant production practices such as adoption of Integrated Pest Management (IPM) strategies improves plant health (DAERA, 2017), thereby reducing the need for antimicrobials and pesticides, preserving their efficacy, and leading to better crop yield at a minimal cost in the long-term.

Specific IPM strategies include.

- 🌿 Use disease-resistant crop varieties, including disease-resistant rootstocks.
- 🌿 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.
- ☞ Deter rodents, wild birds, and other wildlife and livestock from accessing the growing area, as they have been reported to introduce infectious agents as well as drug-resistant microorganisms into farms. Removal of rubbish and clutter from around production sites decreases habitat for rodents and other wildlife. Do not plant crops near dump areas as birds and rodents are attracted to such locations.
- ☞ Practice 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 favor persistence of pathogens.
- ☞ Prioritize use of biological and bio-rational products to control pests and diseases.

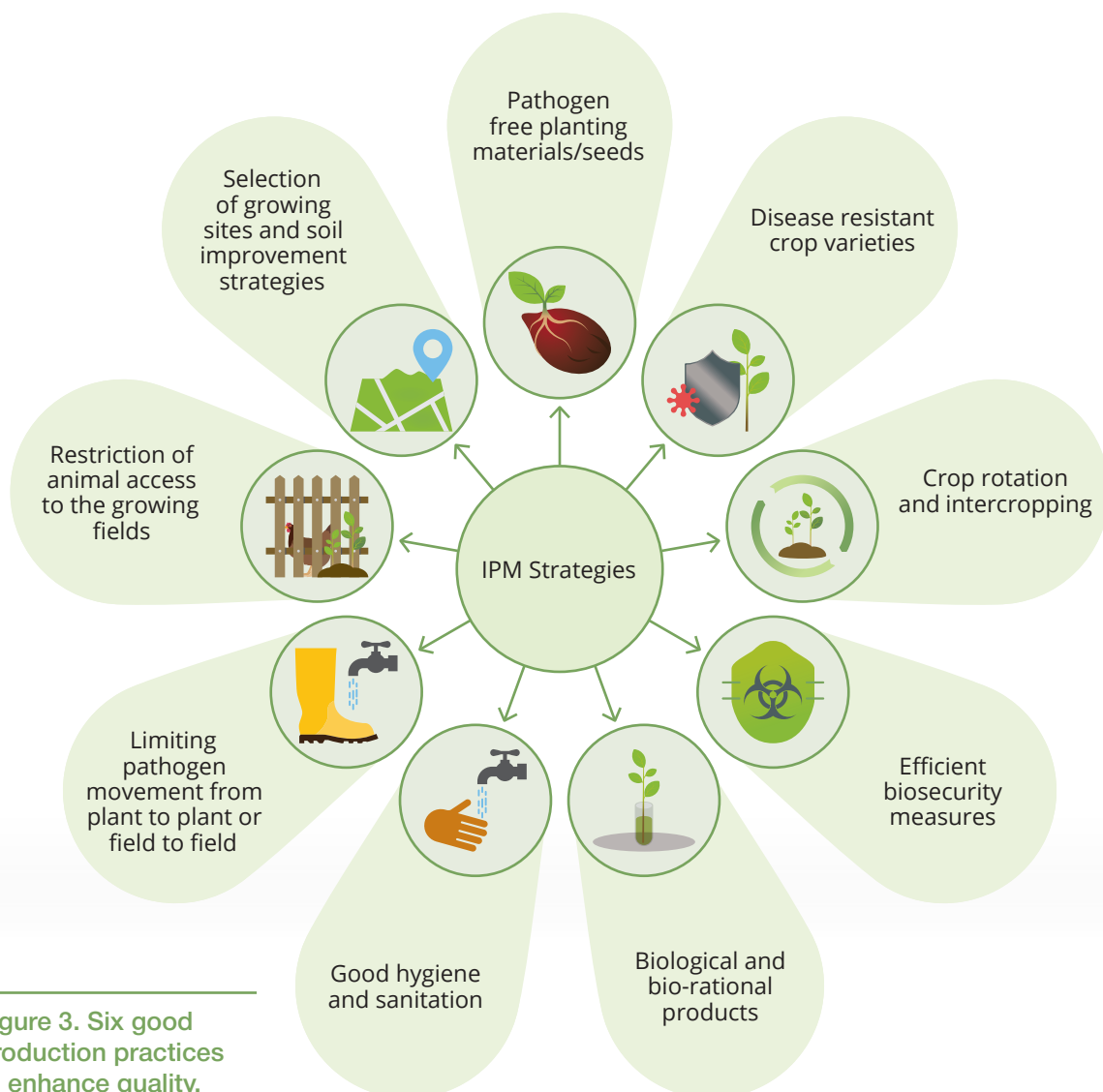


Figure 3. Six good production practices to enhance quality, quantity, and safety.



2

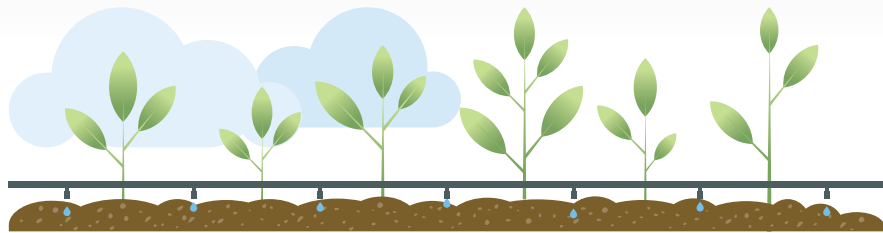
Use water that is fit for purpose

Some plant pathogens are found in irrigation water and are known to cause serious crop health issues. Waterborne plant pathogens such as *Phytophthora* and *Pythium* species attack and colonize plants thereby lowering the quality, decreasing the yield leading to economic losses. Water for irrigation is a primary source of inoculum for *Phytophthora* diseases in fruits and vegetable crops (Hong and Moorman, 2005). Surface runoff from contaminated fields is the most common way to transmit waterborne plant pathogens between farms. Prevent to the extent possible surface runoff from getting directly into your fruit and vegetable farm.

Using contaminated water in preharvest and post-harvest handling can also transmit human pathogenic viruses, like norovirus and hepatitis A virus, and bacteria such as *Listeria monocytogenes*, *Salmonella* spp, and Shiga toxin-producing *Escherichia coli* to vegetable crops (Novak et al 2018; FAO and WHO, 2019; FAO and WHO, 2021). The presence of such pathogens on the product compromises safety thereby increasing the risk of foodborne illness. Reducing microbial contamination of irrigation water and soil are among most effective strategies for the prevention and control of produce contamination (Sangshin et al., 2012). Untreated wastewater effluent from municipal sewage or water adjacent to manured fields should never be used for irrigation purposes as it may contain dangerous pathogens which can contaminate fruits and vegetables and make people sick.

Use only water that is fit for the purpose in irrigation and other pre- and post-harvest handling activities to minimize the risk of transfer of human pathogens to the crop and product (FAO and WHO, 2019). Determining if water is fit-for-purpose can be accomplished using risk assessment tools. Primary factors that are important in determining water's fitness-for-purpose include: 1) the water source (surface vs ground), 2) whether the water will contact the edible portion of the plant, and 3) if the vegetable or fruit is expected to be eaten raw or after cooking. The water used should be of a quality that does not increase the contamination of the product.

Figure 4. Drip irrigation, one way to reduce water contact with edible portion of plants



3

Treat soil amendments to reduce microbial contaminates

Soil amendments such as manure, biosolids and other natural fertilizers are added to a soil to improve its physical properties and enrich the soil. Human and animal manure/excreta used as soil amendment may contain pathogens that cause disease in humans such as Shiga toxin-producing *Escherichia coli* (Oluwadara et al., 2018; FAO and WHO, 2008).

Composting manure properly before application to fruits and vegetables increases the health of the soil and plants, consequently increasing the yield, improving the quality, and reducing the risk of contamination with foodborne and phytopathogens (Sangshin et al., 2012). Manure that is not decomposed properly is not as beneficial to the crops as the nutrients will not be biologically available for plants. To minimize contamination of fruits and vegetables by dangerous microorganisms and optimize nutrient availability to the plants, only use manure, biosolids and other soil amendments that have been properly treated by thorough composting.



4

Ensure farm equipment and containers are clean and dry

If equipment and containers are not kept clean and dry, they may enhance growth of mold that produce fungal toxins called mycotoxins. All farm equipment and containers including pruning, harvesting and storage containers should be cleaned, disinfected, and kept dry. Pruning tool, if not properly decontaminated, can transfer phytopathogenic bacteria (e.g., *Erwinia* spp. and *Xanthomonas* spp.), viroids and viruses (e.g. peach latent mosaic viroid and tomato mosaic virus), and fungal agents (e.g., *Leucostoma* spp. causing perennial canker), between plants. *Listeria monocytogenes*, an important foodborne pathogen, can be found on food contact surfaces in vegetable processing facilities and may be the source of food contamination (FAO and WHO, 2008). Cleanliness of equipment and containers can be achieved by performing the following tasks:

- ☞ Wash, disinfect and dry harvest and storage equipment before use.
- ☞ Brush off visible dirt and debris from the fruits and vegetables in the farm to help prevent the transfer to containers and storage facilities.
- ☞ Store packing containers off the ground in a clean, dry location during and after harvest to prevent contamination by pests, dirt, and water.
- ☞ Limit access of animals and non-workers to the farm, containers, equipment, and storage areas to minimize contamination.
- ☞ Keep the packing area clean and dry. Wet or damp surfaces promote the growth of fungi and mycotoxins production.
- ☞ Clean and sanitize transport vehicles used for haulage of fruits and vegetables to reduce the build-up of harmful microorganisms.



Figure 5. Cleaning of harvest crates



5

Keep animals away from fields and packing facilities

Domestic and wild animals may trample, eat, and destroy the crops leading to reduced yield and quality. The animals may also carry disease-causing microorganisms on their feet, skin and in their manure and transfer pathogens to the crops, compromising safety. Minimize intrusion and dissuade animals from entering or contaminating fields and protected agriculture structure to protect crops. Methods to keep animals and their waste away from fruits and vegetable farms include the following:

- ☞ Exclude animals from fields and protect agriculture with fences, doors, or nets to prevent vermin from entering.
- ☞ Keep livestock downhill from growing fields to reduce risk from run-off.

- Remove trash, food, and water from around farms to minimize attraction and habitat for vermin near growing fields.

Figure 6. Fence barrier to keep animals away from the farm.



6

Practice good hygiene, sanitation, and biosecurity

Farm workers may directly contaminate fruits and vegetables on the farm due to poor personal hygiene. Many plant pathogens are easily transmitted via mechanical routes, for example, tomato mosaic virus (TMV) is transmitted following contact with contaminated clothing. Norovirus, one of the most common foodborne diseases worldwide is transmitted by sick and asymptomatic workers with poor personal hygiene. Good sanitation, hygiene and biosecurity prevent the spread of pathogens between farms, thereby enhancing the safety and quality of the product. The following sanitation and biosecurity measures will minimize the risk of spread of human and plant pathogens to the crops,

workers, and consumers:

- Wash hands with soap and water before handling fruits and vegetables.
- Minimize the number of people accessing the farm.
- Use a disinfecting footbath, or disinfect or change footwear prior to entrance on the farm to minimize the risk of introduction and spread of plant and human pathogens to the crops.
- Change personal protective equipment including boots, masks, gloves, and lab coats worn on an infected field, or another farm or market before going to the healthy field.
- When inspecting farms, visit healthy farms first before visiting those presumed to be diseased to minimize the spread of plant diseases.

Figure 7. Handwashing station.



Conclusion

To produce horticulture products that are safe and high quality, producers are required to adopt the above good production practices to prevent plant diseases, minimize microbiological contamination with zoonotic pathogens and enhance food safety. These practices require investing in sanitation and biosecurity measures, manure composting facilities, water treatment etc. However, the returns on such investment include higher yield, better quality and safe product at minimal cost in the long term.

References

- Department of Agriculture, Environment and Rural Affairs (DAERA). 2017. Integrated pest management guide (IPM). <https://www.daera-ni.gov.uk/integrated-pest-management>
- FAO and WHO. 2021. Safety and quality of water used with fresh fruits and vegetables. Microbiological Risk Assessment Series No. 37. Rome. <https://doi.org/10.4060/cb7678en>
- FAO and WHO. 2019. Safety and Quality of Water Used in Food Production and Processing – Meeting report. Microbiological Risk Assessment Series no. 33. Rome.
- FAO and WHO. 2008. Microbiological hazards in fresh leafy vegetables and herbs: Meeting Report. Microbiological Risk Assessment Series No. 14. Rome. 151pp. <https://apps.who.int/iris/handle/10665/44031>
- WHO 2012. Five keys to growing safer fruits and vegetables: promoting health by decreasing microbial contamination <https://www.who.int/publications/i/item/9789241504003>
- Yangjin Jung, Hyein Jang, Karl R. Matthews (2014). Effect of the food production chain from farm practices to vegetable processing on outbreak incidence. *Applied Microbiology International*. <https://doi.org/10.1111/1751-7915.12178>
- Sangshin Park, Barbara Szonyi, Raju Gautam, Kendra Nightingale, Juan Anciso, Renata Ivanek (2012). Risk factors for microbial contamination in fruits and vegetables at the preharvest level: a systematic review. *Journal of Food Protection*, Vol. 75, No. 11, 2012, Pages 2055–2081. <https://pubmed.ncbi.nlm.nih.gov/23127717/>
- Oluwadara Oluwaseun Alegbeleye, Ian Singleton and Anderson S. Sant’Ana (2018). Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review. *Journal of Microbiology*, Aug; 73: 177–208, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7127387/>
- Novak Babič M, Zupančič J, Brandão J, Gunde-Cimerman N (2018). Opportunistic Water-Borne Human Pathogenic Filamentous Fungi Unreported from Food. *Microorganisms*. Aug 3;6(3):79. doi: 10.3390/microorganisms6030079. PMID: 30081519; PMCID: PMC6164083
- Hong C. X and Moorman G. W (2005). Plant Pathogens in Irrigation Water: Challenges and Opportunities. *Critical Reviews in Plant Sciences*, 24:189–208, DOI: 10.1080/07352680591005838.