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.

Food and Agriculture Organization of the United Nations
Rome, 2024
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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.

- Safe produce protects consumers from foodborne illnesses
- Healthy humans
- Increased revenue
- Safe and high-quality produce:
  - Are more attractive to buyers.
  - Have a longer shelf life.
  - Have more sales opportunities leading to increased profit.
- Increased crop yield and less crop losses
- Healthy plants increase yield leading to greater sales and higher profit margins

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.
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.
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, 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.

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). 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.

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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.
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

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

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


WHO 2012. Five keys to growing safer fruits and vegetables: promoting health by decreasing microbial contamination https://www.who.int/publications/i/item/9789241504003


