Molecular training course to build capacities in Member States. (Photograph courtesy of Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture)

Four coordinated research projects (CRPs) were designed with the support of international senior experts to develop and validate pathogen detection technologies, in order to improve laboratory preparedness and capacity for the surveillance, early detection, control and prevention of major emerging zoonotic diseases in each region. Under the CRP for Asia and the Pacific, three technical contracts were awarded to develop environmental sampling methods (e.g. 'sniffer' technologies).

The FAO/IAEA Agriculture and Biotechnology Laboratories in Seibersdorf worked on the development, testing and/or validation of commercial kits related to the detection of the COVID-19 virus. Eight commercial quantitative PCR-based detection kits were tested and considered suitable and the findings were published in a peer-reviewed journal paper. In addition, two luciferase immunoprecipitation systems (LIPS-N, LIPS-S) were compared with two commercial N-based enzyme-linked immunosorbent assays (ELISAs) for the detection of antibodies against the COVID-19 virus in mink. Results showed that the LIPS-S assay was more accurate than ELISAs for serological surveillance within a naturally exposed mink population, as it provided a lower number of false negative results. Finally, a SARS-Cov-2 assay for antibody detection in different animal species was developed using LIPS. Results indicated the suitability of the assay for the sero-surveillance of COVID-19 virus infection in a range of animal species.

Seeds in Space

Evolution in organisms is driven by mutations arising from exposure to various environmental stimuli. Member States have used radiation-induced mutagenesis and plant breeding to develop improved plant varieties with specific characteristics, including increased yield, enhanced quality, resistance to pests and diseases and suitability for harsh climates. Historically, gamma rays and X-rays have been the predominant agents used to induce genetic variation for plant mutation breeding. However, the unique conditions of microgravity and radiation in space have motivated

a series of biological experiments at the International Space Station (ISS) and in simulated space environments at facilities such as the NASA Space Life Sciences Laboratory. In 2022, the Agency and FAO, through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, ventured for the first time into astrobiology and space breeding with a feasibility study on seed irradiation in space for induced genetic diversity and plant mutation breeding. As part of the study, seeds of the plant species *Arabidopsis thaliana* and *Sorghum bicolor* were sent to space in the cargo of the CRS2 NG-18 mission that launched from NASA's Wallops Flight Facility. These seeds are currently being hosted both within and outside the ISS to increase available knowledge on the effect of cosmic radiation and microgravity on induced genetic variation, and on the use of these phenomena to develop crops that can withstand harsh growing conditions on Earth. The seeds will return from the ISS in early 2023, to be systematically evaluated at the Agency's Laboratories at Seibersdorf to determine the effects of the space environment on genetics and biology.

Antimicrobial Resistance

Agricultural systems are increasingly polluted by antimicrobial substances, including antibiotics used to prevent and treat infections in humans and animals. While these substances save lives, their misuse and overuse are the main drivers for the development of drug-resistant pathogens. The World Health Organization (WHO) has declared antimicrobial resistance one of the top ten global public health threats, causing 700 000 deaths each year and projected to cause 10 million deaths by 2050. To date, the issue has been approached mainly from the human and animal health angles; however, little is known about the impacts of antimicrobial resistance in the environment. It is unknown to what extent antibiotics and resistant bacteria spread through soil and water run-off and via the deep percolation of human and animal waste in agricultural systems. Therefore, it is crucial to gain a better understanding of how antimicrobial resistance moves through soil and water in agricultural systems.

In 2022, through a CRP entitled 'Isotopic Techniques to Assess the Fate of Antimicrobials and Implications for Antimicrobial Resistance in Agricultural Systems', the Agency developed techniques to monitor the pathway of the synthesized antibiotic sulfamethoxazole (SMX) in soil carbon turnover processes based on the application of 13C-labelled glucose and SMX. Compound-specific stable isotopes of carbon and nitrogen as well as stable isotope probing techniques were used to trace the dynamics of SMX in soil, plants and the environment. While these studies effectively showed

Spreading manure to increase soil fertility releases both antimicrobials and their metabolites (antimicrobial genes) into the field. (Photograph courtesy of the Chesapeake Bay Program)

Iranian scientists vaccinate a chicken against avian influenza using an experimental irradiated-inactivated vaccine. (Photograph courtesy of Prof. Farahnaz Motamedi-Sedeh)

that the degradation of SMX led to a loss of soil carbon, additional studies are required to better understand the pathway and dynamics of applied antibiotics and implications for antimicrobial resistance in agricultural systems.

Irradiated Vaccines

There is a great need to accelerate the design and development of new vaccines to protect against emerging and re-emerging pathogens that are difficult to control and can cause devastating epidemics. Within the framework of the VETLAB Network, initial irradiated vaccine projects established the basic parameters required to carry out preliminary experiments in Member States.

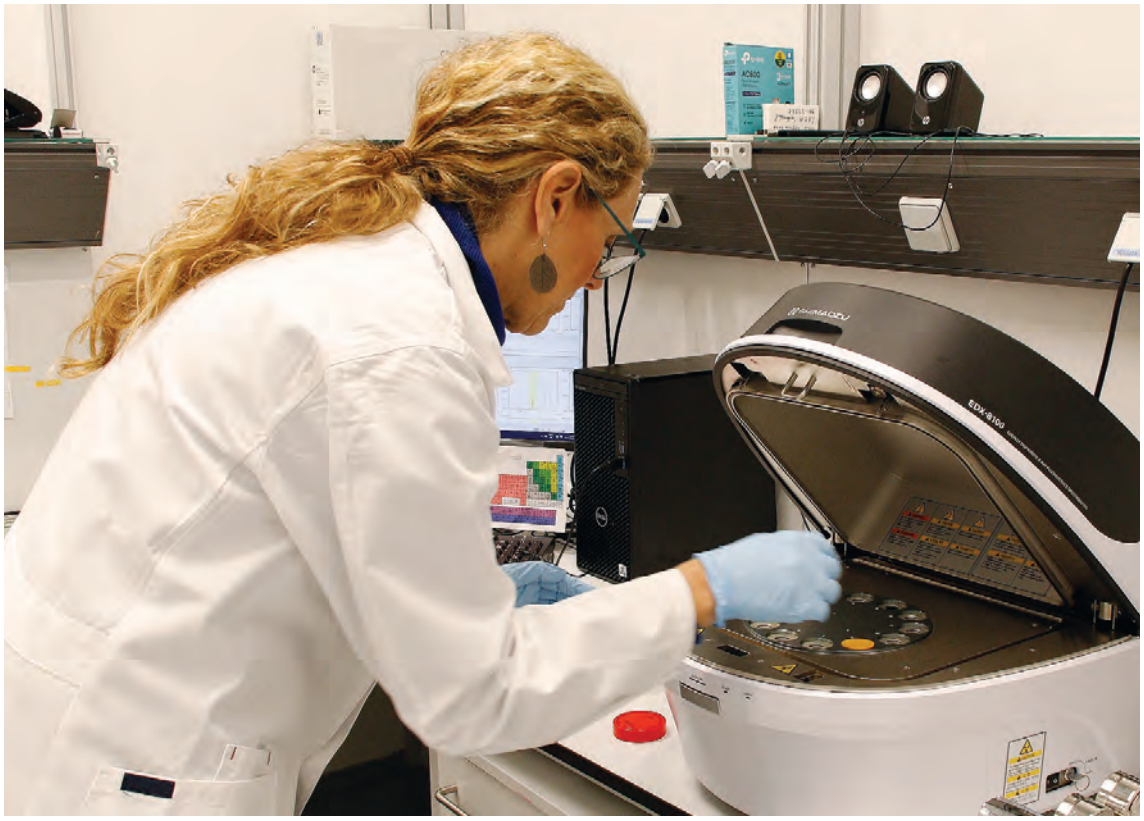
To support participating laboratories further, VETLAB laboratories have developed tools that can be used to evaluate vaccine efficacy. For instance, quantitative PCR panels, which measure innate and adaptive immunity, have been developed for ruminants, swine and poultry. These PCR panels are easy to adopt, which is especially important for collaborating partners that have limited resources to carry out other assays. In addition, a more complex assay that measures vaccine immunogenicity in vitro using bovine monocyte-derived dendritic cells was developed for use as a filter for antigens before proceeding to animal experiments.

Through the Joint FAO/IAEA Centre, the Agency launched a Frontiers research topic on irradiation technologies for vaccine development. There are already 15 articles published under the research topic, including an article on the development of vaccines to protect against influenza, a priority disease according to the One Health approach. Through the research topic it was found that irradiated sterilizing doses maintained structural integrity and vaccine efficacy in all preparations, regardless of the irradiation temperature, and that irradiated vaccine formulations based on inactivated influenza virus demonstrated potential for better performance than conventional vaccines, in terms of both reducing shedding and preventing infection.

Food Safety and Authenticity

Member States face many challenges in ensuring a sustainable, safe and nutritious food supply. Recent events such as the COVID-19 pandemic have highlighted several vulnerabilities in food control systems, including inadequate capability to deal with sudden events that impair operations and to detect and rapidly respond to the emergence of new food-borne diseases and hazards. As such, there is a need for rapid testing methods to improve food safety and quality surveillance. In this regard, nuclear and complementary screening methods can be applied at different points along the food supply chain to aid decision making and ensure that contamination events can be promptly investigated. These methods not only reduce reliance on costly laboratory testing but can also be performed by relatively unskilled personnel.

In 2022, under a project to enhance Member State capacity to rapidly respond to food safety incidents and emergencies, the Agency developed rapid screening methods and laboratory-based methodologies, such as stable isotope ratio and other mass spectrometric measurements, for several techniques including energy dispersive X-ray fluorescence spectrometry, ion mobility spectrometry, surface-enhanced Raman spectroscopy and Fourier transform near-infrared spectroscopy. These methods and laboratory-based methodologies were used to detect toxic Sudan dyes added to spices, palm oil and other commodities with a view to enhancing their perceived quality and value; to verify the geographical origin of commodities such as Thai Hom Mali rice and honey; and to detect residues of agrochemicals such as neonicotinoid pesticides, which are implicated in the decline of pollinating bee populations, in foods. In 2022, more than 240 scientists from 43 Member States were trained by the Agency in these techniques.



Development of a method to test spices for safety and quality using energy dispersive X-ray fluorescence spectrometry at the Joint FAO/IAEA Centre laboratories in Seibersdorf.

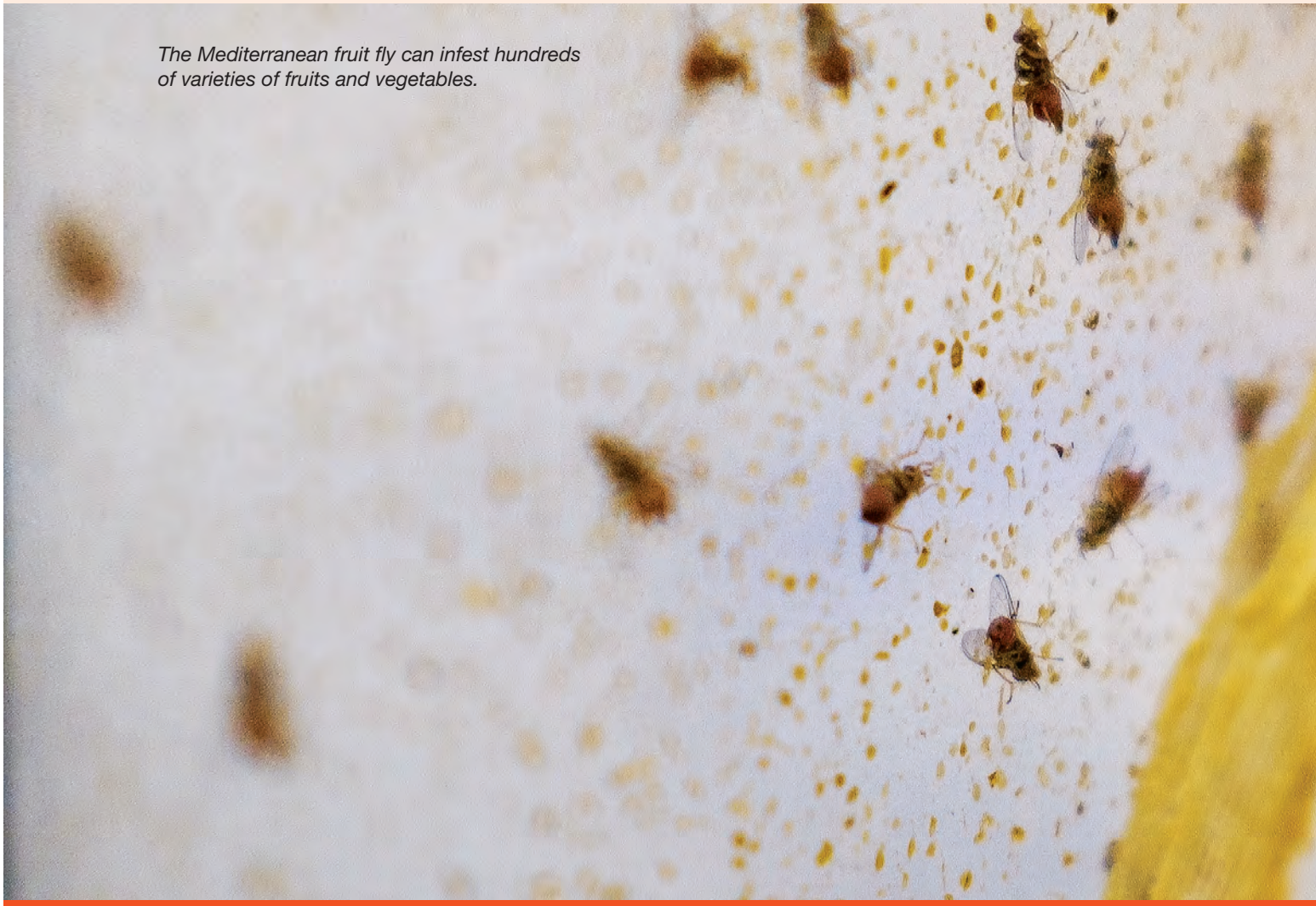
CASE STUDY

Nuclear Technique Successfully Eradicates Dangerous Pest Infestation in Mexico

In 2021, Mexico faced a major threat to its agricultural produce when an outbreak of Mediterranean fruit fly, or medfly, was detected in the country's southwestern state of Colima, near the border with Guatemala. One of the most destructive insect pests affecting fruits and vegetables, the medfly posed a considerable threat to farmers' livelihoods and the country's economy. Just one year later in 2022, the Mexican authorities reported that the outbreak had been successfully overcome with the help of the sterile insect technique (SIT) — a nuclear technique applied under the guidance of the Agency in partnership with the Food and Agriculture Organization of the United Nations (FAO).

The medfly is considered a major agricultural pest because it feeds on a wide range of crops and is difficult to control. After the insect lays its eggs inside a fruit, the larvae feed on the fruit's flesh, rendering it inedible and unsellable. The Colima outbreak posed a serious threat to Mexico's production of oranges, figs, mangoes and papayas, among other agricultural products.

Various methods can be applied to control medfly infestations, some of which are costly and could have negative impacts on crops and the environment. In contrast, the SIT is one of the most efficient and environmentally friendly control methods. Serving as a form of birth control for pests, it involves the mass rearing and sterilization of male insects using low doses of ionizing radiation. When those insects are subsequently released into nature, they mate with wild females but produce no offspring. As a result, the insect population gradually shrinks and is eventually eradicated. This is the second time the SIT has helped eliminate the medfly threat in Mexico — in 1982, national experts used the nuclear technique to effectively wipe out the pest.



The Mediterranean fruit fly can infest hundreds of varieties of fruits and vegetables.

CASE STUDY

As pests can cross borders easily, it is important to be able to respond quickly to new outbreaks when they occur. Following the 2021 outbreak, Mexico opened a new facility specially designed with Agency assistance to produce sterile insects. The second largest facility of its kind in the world, it is capable of rearing one billion sterile flies per week. The goal is to consolidate the current containment barrier at Mexico's border with Guatemala and gradually eliminate the medfly from an area stretching from Guatemala all the way to Panama.

"In the past, the Mediterranean fruit fly has been a big threat to the horticultural industry in Mexico and we have developed large scale programmes to defeat and contain its spread along our southern border", said Maritza Juarez Durán, Director of the National Fruit Fly Programme (PNMF) at Mexico's National Service for Food Health, Safety and Quality (SENASICA). "The detection of this pest in Colima in April last year, 1300 km from the closest wild populations located in the state of Chiapas, at the border area between Mexico and Guatemala, was alarming and we value the IAEA's and FAO's support in helping us bring it under control."

After receiving an emergency request from Mexico, the Agency and FAO responded immediately, organizing on-site visits by individual experts who reviewed the emergency response deployed by the Mexican plant protection organization and provided recommendations for adjusting the eradication strategy. In addition, a technical advisory panel led by Agency staff reviewed the implementation of the eradication actions and provided advice on the post-eradication phase and on regaining 'fruit fly free' status. Specific materials and equipment were also supplied to support the eradication activities.

Mexico is the world's seventh largest exporter of agricultural products and the use of the SIT helps keep these products free from invasive pests, ensuring food security in the region. The Agency continues to assist and work with Mexico through national and regional technical cooperation projects, and through the PNMF, an Agency Collaborating Centre.