Food and Agriculture

Objective

To support Member States in improving efficiency and sustainable intensification of agricultural production and the improvement of global food security through capacity building and technology transfer to Member States. To use nuclear techniques to increase the resilience of livelihoods to threats and crises that impact agriculture, livestock and food security, including climate change, biothreats, food safety risks, and nuclear or radiological emergencies.

Mutation Breeding for Disease Control in Tropical Plants

New outbreaks of plant diseases and pests, and increases in their intensity, have a serious impact on crop production, food security, farmers' incomes and national economies. Tropical race 4 (TR4) of the soil-borne pathogen Fusarium oxysporum, which causes Fusarium wilt, is rapidly spreading in banana production systems globally thereby threatening the banana crop, which ranks among the world's top ten staple foods (Fig. 1).

FIG. 1. TR4-diseased banana plant showing yellowing and wilting of leaves and stem, Guangdong, China.

Following the most recent report of the arrival of this deadly disease in the Andean region in 2021, the Agency responded rapidly by focusing on immediate coordination, capacity building and a holistic approach to combat the disease by targeting genetic diversity and resistance, disease detection, diagnostics and surveillance, and phytosanitary measures.

Another important plant disease of the tropics is coffee leaf rust, which threatens coffee production systems in Mesoamerica. Innovative research in plant mutation breeding at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture has led to the development of resistance screening methodologies, the identification of tolerant or resistant mutants, and the application of techniques that accelerate the breeding process, such as single-cell regeneration and mutagenesis, in coffee. Single-cell mutagenesis, unlike seed mutagenesis, is considered to produce chimera-free plants.

Isotopic Tracing to Identify Sources of Greenhouse Gases from Agriculture

The Agency is developing and validating new methods for the quantification and identification of greenhouse gases in close collaboration with the Institute for Plant Ecology at Justus Liebig University Giessen, Germany (Fig. 2). Greenhouse gas emissions from agriculture account for more than 25% of total greenhouse gas emissions and are generated by numerous microbial processes. The methods to identify the individual production processes involve the use of nuclear techniques and in particular the application of stable isotopes such as nitrogen-15 and carbon-13. The research is pivotal in developing effective mitigation methods for greenhouse gases. Furthermore, some gases such as nitrogen, which play an important role for the nitrogen balance of ecosystems, are very difficult to quantify and require the application of advanced isotopic techniques. The research is essential for a country to be able not only to report on its emission factor, but also to develop effective techniques to ultimately reduce greenhouse gas emissions. As a result of the collaboration with Justus Liebig University Giessen, a comprehensive book on greenhouse gas mitigation

FIG. 2. Soil incubation in a climate chamber in the soil laboratory of Justus Liebig University Giessen, Germany.

methodologies was published aimed at scientists, technical experts and those working in the industry. The book provides practical methods for applying nitrogen-15 tracing techniques to accurately measure nitrous oxide.

Veterinary Laboratory Capacity Building for Surveillance and Early Diagnosis of Zoonotic Diseases

The intensification of farming systems, increased movement of animals due to world trade, and alterations in the geographical distribution of pathogens and their vectors brought about by climate change and variability are impacting the incidence and distribution of transboundary animal and zoonotic diseases, threatening food security, biosecurity and livelihoods. Cost effective nuclear and nuclear derived immunological and molecular diagnostic techniques, including radio- and stable isotopes, are assisting Member States in the identification, assessment and control of endemic, exotic and zoonotic diseases, including those with biothreat potential. In addition, newly developed approaches to veterinary vaccines, including irradiated vaccines, and stable isotopic techniques for tracing and monitoring bird migration are being implemented. Capacities have been enhanced in more than 40 Member States for the surveillance and control of foot-and-mouth disease, avian influenza (Fig. 3), peste des petits ruminants, Rift valley fever, Ebola, African swine fever, lumpy skin disease, trypanosomosis and capripox viruses, and support has been provided to more than 129 Member States for the detection and control of the SARS-CoV-2 virus that causes COVID-19, under the Agency's Zoonotic Disease Integrated Action (ZODIAC) initiative. The Veterinary Diagnostic Laboratory Network (VETLAB Network) continued to provide emergency and routine support to strengthen laboratory capacities for the diagnosis, detection and control of transboundary animal and zoonotic diseases (Fig. 4). In 2021, nearly 600 professionals and technicians participated in several virtual workshops and technical meetings on early detection and characterization of animal and zoonotic pathogens.

FIG. 3. The highly pathogenic avian influenza H5N1 virus can be spread by wild birds.

FIG. 4. Sample collection from wild animals requires high protection and handling standards learned through proper on-site training.

Improvement of the Sterile Insect Technique Package for Human Disease Vectors, Particularly Aedes Mosquitoes

After the outbreak of Zika in late 2015 and early 2016 in Latin America, Member States supported Agency activities to accelerate the development of the sterile insect technique (SIT) and its transfer to field trials as an environmentally friendly technology to control mosquitoes. In the last five years, progress has been made on all components of the SIT package for *Aedes* mosquitoes, leading in 2021 to a significant reduction in the cost of mass production of sterile males through innovative cage and rack designs, and through the development of insect-based diets for mosquito larvae. In addition, procedures for the irradiation of adult mosquitoes were developed. Finally, the handling and transport of male mosquitoes has been improved and drones which allow the release of male mosquitoes in urban environments were developed (Fig. 5).

The unintentional release of female mosquitoes should be avoided as much as possible, as it is the female mosquitoes that transmit the disease. Automatic sex-sorters can help to avoid this risk. The Insect Pest Control Laboratory at Seibersdorf has validated such sex-sorters for several species and strains that were developed by Member States. In addition, researchers produced genetic sexing strains for *Aedes aegypti* by using genes that determine two different eye-colour phenotypes, namely red and white, as selectable markers.

These innovations have been transferred to numerous Member States. Several countries tested or are now testing the technology in field trials, including Brazil, China, Cuba, France, Germany, Greece, Indonesia, Italy, Mexico, Singapore, Spain, Sri Lanka and the United States of America. First successes in reducing human disease transmitting mosquitoes were recorded on a small scale. The collaboration between the Joint FAO/IAEA Centre and the World Health Organization has been strengthened to prepare field tests of the technology against human diseases transmitted by mosquitoes.

FIG. 5. Drone releasing sterile male mosquitoes (Aedes aegypti) on Réunion Island, France.

CASE STUDY

Nuclear Techniques Help the Textile Industry Thrive in Pakistan

Cotton is key to the economy of Pakistan, where the textile industry contributes 8.5% to gross domestic product and accounts for 60% of the country's exports. However, climate extremes such as heat waves and increasing temperatures have taken their toll on cotton, causing an unprecedented fall in yields in recent years.

The Agency, in partnership with the Food and Agriculture Organization of the United Nations (FAO), is working with local experts to develop and introduce new varieties of cotton through plant mutation breeding. This technique uses gamma rays to irradiate cotton seeds and produces new varieties more resilient and better adapted to the new climate reality. New varieties developed in this way account for 40% of all cotton produced in the country, up from just 25% two years ago and 0% in 2016.

"Year on year variation in yields of the cotton crop due to climate change is not only impacting the farming industry negatively, but it is also straining development of the entire cotton-based value chain in the region," said Manzoor Hussain, Deputy Chief Scientist and cotton breeder at the Nuclear Institute for Agriculture and Biology (NIAB). "Agriculture is central to Pakistan's economy, and cotton has a significant role in driving the economy of the country. Through nuclear techniques, we can ensure that this economic area remains profitable."

By harnessing nuclear technology, new cotton varieties tolerant to heat waves and rising temperatures are helping maintain the cotton industry in Pakistan.

The Agency's support and training in plant mutation breeding and selection has helped pave the way for NIAB to release four cotton varieties in the past five years. The popularity of these varieties has been steadily growing.

"I was able to harvest my crop this year with a 30% higher yield than what I could achieve with traditional varieties," said Muhammad Ikram, a farmer from the Bahawalnagar District, 500 km south of Islamabad.

To support the textile industry, which employs 40% of the labour force in the country, the release of new cotton varieties continues. These new varieties have higher yields and improved fibre quality, as well as good agronomic performance and adaptability to climate change variation.

Collaboration between NIAB, the Agency and FAO also includes a long term technology transfer and capacity building programme. The partnership has included training events, workshops and fellowships; training Pakistani scientists in plant breeding techniques focused on developing cotton varieties tolerant to drought and high temperatures.

Through this long-standing collaboration, Pakistani scientists have reached a level of expertise that they can share with specialists in neighbouring countries that are in the early stages of mutation breeding. With this combination of suitable facilities, technical know-how in cotton mutation breeding and improved cotton varieties in the field, NIAB now hosts Agency training for experts from across the region.