Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

The FAO/IAEA Agriculture and Biotechnology Laboratories

In the service of Member States

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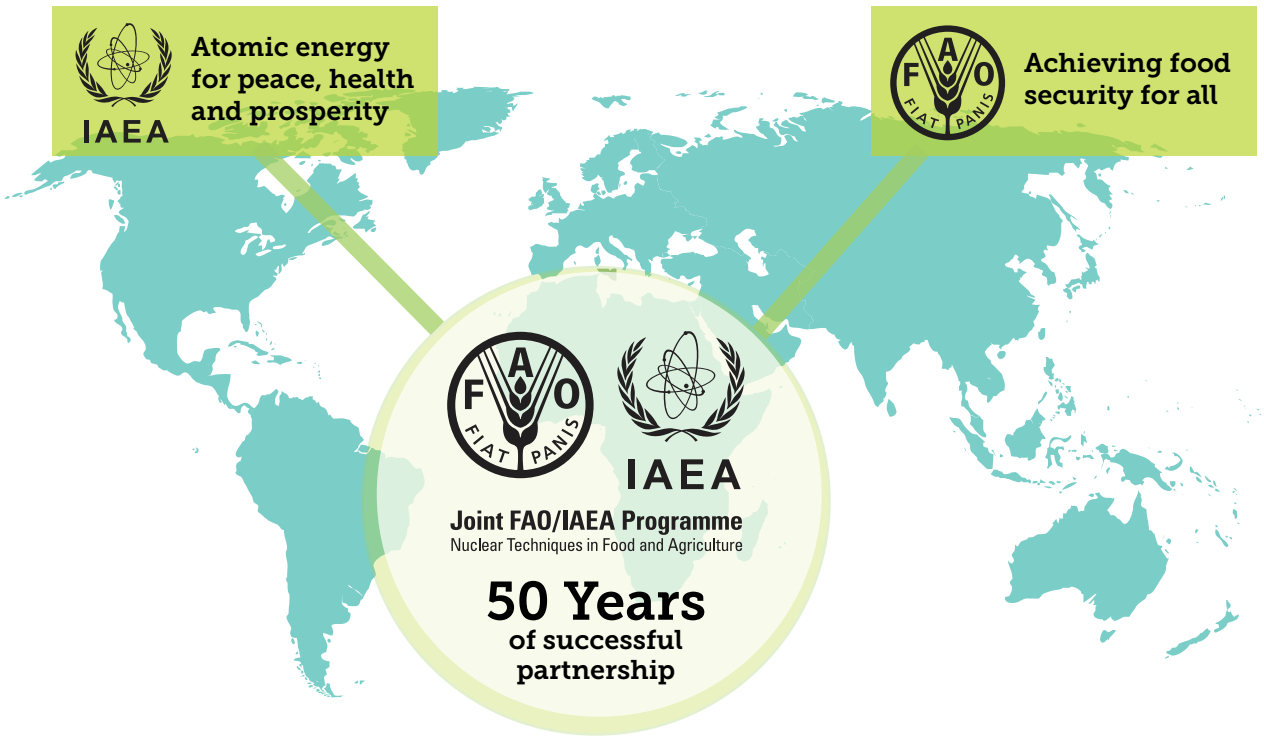
Introduction

It was in 1964 when the Food and Agriculture Organization of the United Nations (FAO) and the International Atomic Energy Agency (IAEA) took the visionary step of merging their mandates to create the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. The goal was to use the talents and resources of both organizations to develop and adapt nuclear techniques and related technologies to assist their Member States with solving problems in the area of food and agriculture. As an integral part of the Joint FAO/IAEA Division, the FAO/IAEA Agriculture and Biotechnology Laboratories have proven to be a unique collaborative model in the UN system, playing a pivotal support role in the success of nuclear applications for food and agriculture.



Situated 35 km from their headquarters in Vienna, Austria, the FAO/IAEA Laboratories specialize in applied research as part of the Joint FAO/IAEA Programme that includes developing, adapting and transferring appropriate isotope and radiation technologies of importance to agriculture – technologies designed to meet specific local needs and environmental conditions. The Laboratories also provide support services and technical training for scientists from Member States, including guidance on the application of technologies, the underpinning science and its hands-on use. They also provide training on practical aspects such as the maintenance of laboratory equipment, which, in turn, ensures the adoption of best practices in safety and quality control.

The FAO/IAEA Laboratories spearhead the use of "atoms for peace", with particular emphasis on research for development. Their extraordinary expertise is often at the forefront of worldwide efforts to fight global hunger and malnutrition, improve environmental sustainability, protect plants and livestock, improve farmers' incomes and ensure safe food for consumers. The socio-economic impact achieved by the application of these technologies is measured in billions of US dollars annually.

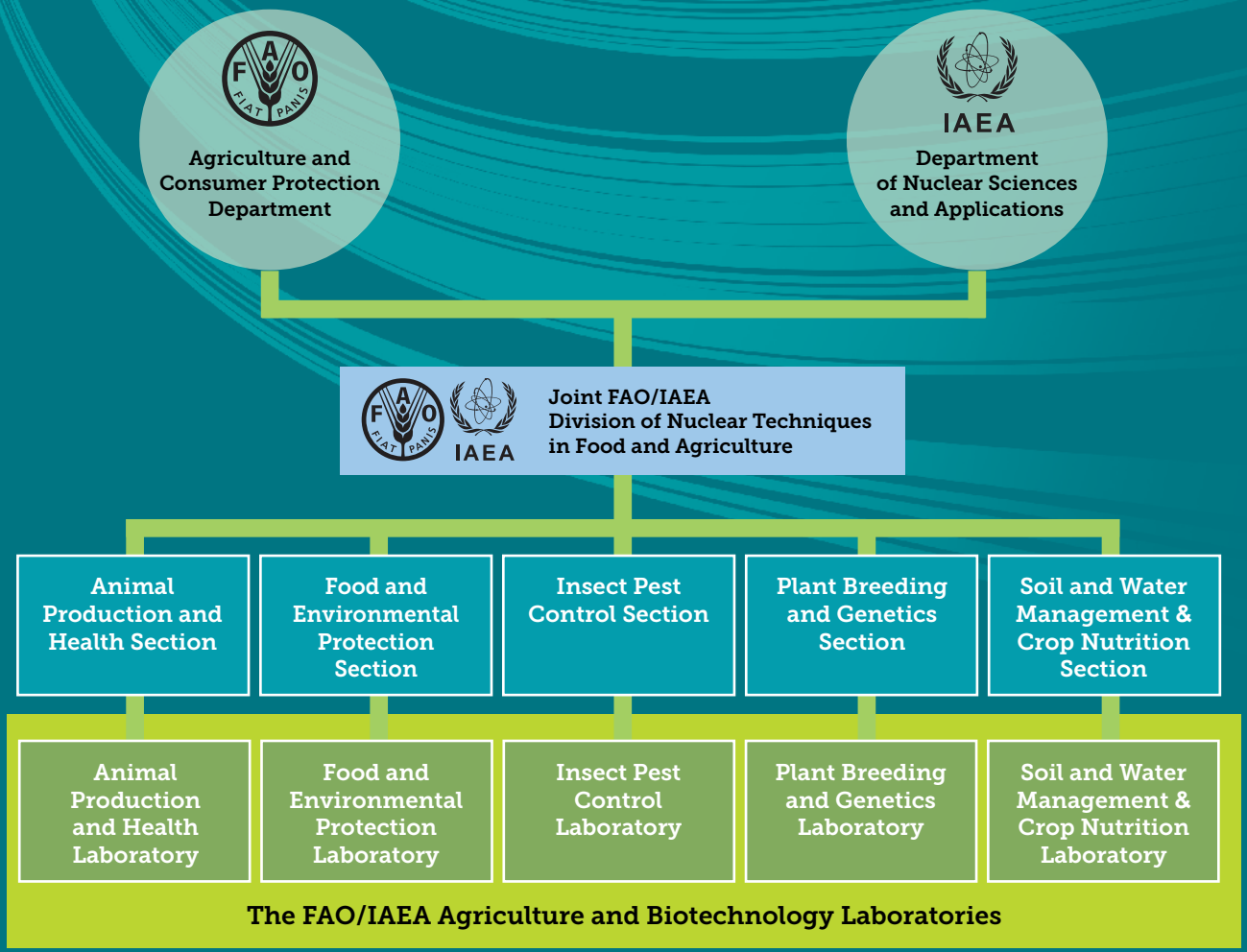
The mandate of the Joint FAO/IAEA Division, and the Laboratories, is to assist Member States in the safe and appropriate use of nuclear techniques and related technologies in food and agriculture. Applying cutting-edge isotope and radiation technologies – developed by the Joint FAO/IAEA Programme – to these sectors adds enormous value to global agricultural research in the areas of animal production and health, food and environmental protection, insect pest control, plant breeding and genetics, and soil and water management and crop nutrition.

The Mission

It starts with a need

All the activities of the FAO/IAEA Laboratories are demand-driven in response to the specific needs and requests of Member States and are an integral part of the Joint FAO/IAEA Programme. Responses provided to such requests are conceived, planned and executed upon review and endorsement of the governing bodies of the IAEA and FAO.

Organizational Chart



The Mission of the FAO/IAEA Laboratories is Focused on:

Applied research and development

The research and development (R&D) activities undertaken at the FAO/IAEA Laboratories are linked to coordinated research projects (CRPs) and technical cooperation projects (TCPs). These are the Joint Division's two main delivery mechanisms for developing and transferring nuclear and nuclear-related technologies to Member States. These activities play a central role in most CRPs and provide technical backup to TCPs. The Laboratories provide crucial input and innovative solutions to national and global agricultural development challenges; provide vital scientific evidence to support the solutions; and support decision- and policy- making as well as international standards.

Training and capacity building

These activities are essential components of technology transfer. While almost 90 per cent of the Laboratories' training activities are conducted in Member States, numerous training courses, workshops, seminars and individual fellowships are also held each year at the Laboratories to validate or harmonize procedures. These involve several hundred trainees annually, with the overall goal of building sustainable capacity in each Member State. While the main focus is nuclear and nuclear-related technologies, emphasis is also placed on understanding the wider aspects of the problems to be studied and solved. This ensures that the trainees return to their home country properly equipped with the knowledge needed and extensive scientific and technical networks ready to assist them whenever required.

Training activities at the FAO/IAEA Laboratories are generally linked to TCPs and are commonly funded through the Technical Cooperation Fund. They may also be funded by the Joint FAO/IAEA Division itself through extra-budgetary funds or by a Member State. Training activities are related to specific topics and requests and may take the form of i) training courses with 20-25 participants each and lasting generally from one to six weeks, ii) workshops with around 10 participants and lasting for one to two weeks or iii) individual fellowships or internships that may last from three months to a year or more. Trainees are proposed by the individual Member States and assessed for appropriate experience and suitability by the IAEA prior to being accepted for participation in such training activities. The Laboratories also host numerous scientific visitors and graduate students each year.

Technical and analytical services

The FAO/IAEA Laboratories provide technical and analytical services to Member States. These services include, amongst others, radio sensitivity testing to determine optimal dose rates of gamma or x-ray irradiation; mutation induction treatment with gamma and x-rays; proficiency testing; and evaluation, method development, validation, standardization and selection of appropriate equipment and processes for specific uses. Laboratory staff also share with trainees and partners their extensive experience in niche and routine operations and processes, as well as in the maintenance and repair of equipment.

Research for Development
Major Thematic Areas

The FAO/IAEA Laboratories' extensive capabilities in applied research and development, capacity building and the provision of technical services provide strong support to the IAEA's mission to develop nuclear and related technologies for peace, health and prosperity, and FAO's strategic objectives to end hunger, malnutrition and rural poverty, while making agriculture more productive and sustainable.

The FAO Strategic Objectives

- **Help eliminate hunger, food insecurity and malnutrition**
- **Make agriculture, forestry and fisheries more productive and sustainable**
- **Reduce rural poverty**
- **Enable inclusive and efficient agricultural and food systems**
- **Increase the resilience of livelihoods to disaster**

Some one billion of the world's poorest people depend on livestock for their day-to-day livelihoods, both as a source of food and to generate the power necessary to tend their fields. To reduce poverty and ensure global food security, there is an urgent need to increase livestock production. The Animal Production and Health Laboratory (APHL) assists Member States in their efforts to improve livestock productivity through the more efficient use of locally available feed resources, the development of improved management and breeding practices for indigenous and adapted animals, and the development of diagnostic tools and prophylactic measures for the control of important animal diseases.

Animal Production and Health LABORATORY (APHL)

Animal Health

Early and rapid diagnostic platforms. An important achievement of the Global Rinderpest Eradication Programme was the APHL's development, in cooperation with its partners, of diagnostic in cooperation with its partners, of diagnostic tests for the large-scale monitoring of rinderpest vaccination campaigns and disease surveillance in the field. APHL was also the driving force in establishing the rinderpest laboratory network and in introducing quality diagnostic and epidemiological systems in Member State laboratories. Building on that success, the APHL today is focusing its globally unique capacity on some of the world's most important transboundary diseases, including highly pathogenic avian influenza, foot-and-mouth disease, African swine fever, capripox diseases and peste des petits ruminants, the next livestock disease targeted by the FAO and the World Organisation for Animal Health (OIE) for global eradication.

Traceability of animals. Another key research area for the APHL is the use of nuclear and related techniques to trace transboundary animal movements and to investigate the epidemiology and ecology of concomitant pathogens. The most recent focus of this work has been on bird migrations and the associated highly pathogenic avian influenza. A recent finding that the concentration of stable isotopes in inert animal tissues correlates with their spatial distribution in the environment and is sufficiently constant to reflect migratory pathways, and the detection of both bird and virus DNA in faeces may

provide a model platform for monitoring migration and disease epidemiology in both long- and short-range migrants.

Irradiated vaccines. While numerous live vaccines against viral and bacterial pathogens have been successfully developed, there has been less success with parasitic diseases. Recent developments in pathogen irradiation technology and immunology now make it possible to ascertain the specific cellular immune response to parasitic pathogens and hence to assess the protective quality of potential vaccines. A major focus of the APHL is the development of vaccines based on the irradiation of pathogens to inactivate multiplication while maintaining a temporary capacity to synthesize proteins that may induce a better immune response. Current emphasis is on the development of an irradiated trypanosome vaccine to control African trypanosomosis in animals, a devastating disease that prevents sustainable and profitable livestock farming in almost two-thirds of sub-Saharan Africa.

Animal Production

Animal genetic resources for reproduction and breeding platforms. The APHL is also playing an important role in countering threats to livestock biodiversity. It supports Member States in implementing the Global Plan of Action on Animal Genetic Resources (GPA-AnGR) through capacity building and transferring technologies related to the evaluation and characterization of animal breeds. Local animal breeds generally possess valuable traits, such as adaptation to extremely dry conditions or resistance to parasites or infectious diseases. The APHL utilizes radiation hybrid panel mapping technologies to map genes responsible for disease resistance and develops DNA marker tools to identify and exploit useful trait characteristics. Current research targets the breeding of sheep and goats with resistance to gastro-intestinal parasites, a disease that causes global annual losses exceeding US $10 billion. This research is being linked to the creation of web-accessible databases to enable counterparts in Member States to assess genetic diversity within their own indigenous livestock breeds. Together, this will enable a uniquely-focused, national breeding response to rapidly occurring environmental changes.

Food and Environmental Protection LABORATORY (FEPL)

Consumers worldwide benefit from trade globalization through improved access to an increased variety of food products, year-round supplies and competitive prices. However, a globalized food supply can also introduce new food safety risks, revive previously controlled hazards and potentially circulate fraudulent or contaminated food. The Food and Environmental Protection Laboratory (FEPL) assists Member States in establishing effective food traceability and food contaminant control systems to support food safety. The FEPL also helps implement authenticity and chemical residue testing that ensures food quality and combats economic losses, including the illegal production and marketing of counterfeit and adulterated food products. This helps Member States not only improve local food safety but also benefit economically through their participation in international trade.

Controlling food contaminants

Chemical contamination. Food consumers fear residues from pesticides, food additives, livestock drugs, environmental toxins and persistent chemical pollutants. A major focus of the FEPL relates to food safety and the control of food contaminants, such as mycotoxins and the residues of pesticides and veterinary drugs. It develops and transfers analytical methods and procedures, and provides expertise and services that enable Member States to generate the validated analytical data essential to ensure effective food control systems. In addition, the Laboratory helps to establish the use of appropriate detection methods and promotes policies for providing feedback to regulators, farmers/producers and the post-production industry on the effectiveness of regulations and practices put in place to ensure food safety and quality and protection of the environment.

Establishing traceability

Authenticity of food products. Trade in counterfeit food products is an important issue for the global food trade, diminishing consumer trust, eroding market confidence and raising concerns of significant health risks. FEPL's work centres on combating food fraud by applying nuclear and related techniques to determine the geographical origin or to ascertain the composition of food. Such authenticity work focuses on foods that are most commonly suspected of being misrepresented and employs innovative isotopic and related techniques that can be transferred to Member States. The FEPL strategy includes encouraging and fostering the involvement of all food supply chain stakeholders in order to ensure that the work of the food control laboratories, the primary counterparts in FEPL projects, is sustainable and strategically focused.

Isotopic food fingerprints – Mother Nature's barcode. An essential element of food safety is the ability to trace food products to their source in order to facilitate corrective actions whenever problems are detected. The traceability of products across international boundaries is a key requirement in assuring food safety; it may also be important for economic, religious or cultural reasons. Analytical techniques to determine and corroborate the origin of food provide an independent means of verifying 'paper traceability systems' and also help to prove authenticity, to combat fraudulent practices and to control adulteration.

FEPL collaborates with other expert laboratories in applied research and method development for food product and contaminant traceability using chemical measurements of the food itself.

These techniques include stable isotope measurements and complementary methods such as elemental and metabolomic fingerprinting – a profile of naturally occurring chemicals in the food. These techniques to authenticate provenance, along with complementary methods for the detection of residues and contaminants, provide an effective package of analytical tools that are transferred to Member States to address emerging food safety and quality issues and support holistic food safety systems.

Consumers worldwide expect their agricultural produce to be free of pesticide residues. Biological pest control methods, including the sterile insect technique (SIT), are a proven and reliable way to satisfy this important expectation. The environmentally-friendly SIT pest control method involves the mass rearing of the target insect pest, followed by their sterilization and systematic release over the target areas. As released sterile males mate with wild virgin females no offspring are produced, eventually causing the native pest population to decline or become extinct. Research and development activities at the Insect Pest Control Laboratory (IPCL) are aimed at developing, improving and validating the use of the SIT as a component of area-wide integrated pest management programmes against selected major insect pests. The IPCL is recognized worldwide as the leading global centre for research and development related to the SIT.

Insect Pest Control LABORATORY (IPCL)

Control of plant pests

Fruit flies are among the most devastating pests of agricultural crops, and their presence in Member States has significant consequences for international trade. Research at the IPCL focused initially on the Mediterranean fruit fly. As the SIT technology for this species matured, focus in the last decade has widened to other fruit fly pests. The IPCL maintains more than 35 strains of fruit flies as an important repository for Member States, including several genetic sexing strains and more than 200 mutant strains. Its current focus is on the *Anastrepha* (Latin American) and *Bactrocera* (African and Asian) pest species; the improvement of male quality using hormonal, semiochemical and dietary supplements; the mating competitiveness and compatibility of strains; the assessment of transgenic strains; the cytogenetic and productivity characterization of genetic sexing strains; and the study of symbionts and pathogens.

Control of livestock pests

Tsetse flies are considered one of the root causes of poverty in sub-Saharan Africa. They are blood-feeding insects that transmit parasites that cause sleeping sickness in humans and nagana in livestock. There are 8–10 tsetse species of economic importance that seriously impede the development of sustainable and efficient livestock production systems. The IPCL maintains colonies of five tsetse fly species, while its research focuses on the development of semi-automated feeding and holding units; understanding the biology of the salivary gland hypertrophy virus to enable the development of virus management strategies; methods

to enhance vector refractoriness; the development of a pupal sexing system using near-infrared spectroscopy; the development of alternative blood decontamination methods; and the evaluation of x-ray irradiator systems for insect sterilization.

Control of mosquitoes

Mosquito-borne diseases such as malaria, dengue fever and chikungunya are among the most devastating human health problems. The parasites and viruses are transmitted by the female mosquitoes and are responsible for more than one million deaths each year. They are also a major obstacle to the UN's poverty reduction efforts. The IPCL recently embarked on an assessment of the feasibility of developing a SIT package for the control of selected species of mosquitoes. Its research focuses on the development of mass-rearing equipment and quality control techniques; the study of symbionts; radiation sensitivity studies; and an assessment of the competitiveness of sterile male mosquitoes.

Genetic sexing methodologies

The SIT invariably relies on the ability of released sterile male insects to effectively compete and mate with native female counterparts. The release of sterile females in most cases reduces the efficiency of the technique and is a substantial additional financial burden to the cost of mass rearing. The IPCL has therefore developed genetic sexing strains, including one based on female temperature sensitivity in Mediterranean fruit flies, that enable the separation of males from females as early as possible in the life cycle and which is currently utilized in virtually all SIT programmes against this pest. The IPCL is currently working to develop similar genetic sexing mechanisms in mosquitoes.

Plant Breeding and Genetics LABORATORY (PBGL)

As Member States struggle to deal with the negative impact of climate change and variability – including droughts, temperature extremes, storms and salinity, loss of plant diversity and new and re-emerging plant diseases – they must also face the huge challenge of how to feed the world's growing population. This now exceeds seven billion people, of which FAO estimates that more than 800 million are chronically undernourished. Countries must deal with increasingly unpredictable and hazardous weather patterns, variable harvests and worsening exposure to pests, diseases and drought. Activities carried out in the Plant Breeding and Genetics Laboratory (PBGL) in plant mutation breeding offer agriculturists in both developed and developing Member States the opportunity to develop new and more robust crops adapted to these challenges, adding to our agricultural biodiversity.

Mutation induction

Activities at the PBGL are aimed at assisting national plant breeding programmes in the use of mutation techniques and associated modern biotechnologies to develop improved varieties of both major and under-utilized food and industrial crops. Mutation induction is carried out by the treatment of plant parts (usually seeds) using gamma or x-ray irradiation. The PBGL provides a service to Member States in plant mutation induction and continues to develop protocols for effective treatments. New methods in mutation induction (e.g. the use of an ion beam) are also being investigated. The PBGL is recognized globally as a centre of excellence for plant mutation induction and over 80 per cent of Member States have requested these services.

Mutation detection

The detection of novel induced mutations has long been a bottleneck in plant mutation breeding. However, with recent breakthroughs in high-throughput mutation detection technologies, the PBGL is assisting Member States in acquiring and establishing appropriate capacities to increase the efficiency of screening for desired traits and to accelerate the development of mutant lines into commercial varieties for farmers. In doing so, the PBGL develops and disseminates simple and user-friendly protocols for the phenotyping (plant-based) and genotyping (DNA-based) of target traits in a wide range of crops that can be easily validated and adopted by Member States. Current priorities are to develop and disseminate screening protocols for important biotic and abiotic stress-related traits, such as pest and disease resistance and tolerance to drought, heat and salinity. The PBGL recently generated protocols for low-cost DNA extraction and analysis, and for the screening of salt tolerance in rice and other cereals, such as wheat and barley, and is currently developing screens for disease resistance.

Boosting biodiversity

Mutation is a natural process that drives biodiversity and thus evolution. The collective output of mutation induction and detection is to provide greater biodiversity to plant breeders, more specifically to develop novel desired traits in relevant breeding materials. Typically this is done by inducing mutations in a leading crop variety that has become susceptible to a new environmental threat. This is advantageous because the desired trait may not already exist in breeding material or may be extremely difficult to introduce into elite breeding lines. The PBGL aims to speed up this process and to deliver new traits directly into farmer-preferred varieties. It is a fast, non-GMO technique to enrich biodiversity in important crop varieties.

Soil and water are vital for food security. Despite the importance of these resources, approximately five to seven million hectares of land are lost each year through inappropriate soil management while the estimated global water use efficiency in agriculture is a mere 40 per cent. In addition, climate change has become a major threat to global food security, with changing weather patterns bringing storms, floods, droughts and extreme temperatures. Nuclear technologies play an increasingly crucial role in assessing the impacts of climate change and variability on soil and agricultural water resources, and in establishing effective soil, water and crop management packages for climate change mitigation and adaptation. More recently these technologies are also being directed towards the enhancement of nuclear emergency response. The Soil and Water Mangement and Crop Nutrition Laboratory (SWMCNL) uses nuclear technologies to address these global issues.

Soil and Water Management and Crop Nutrition LABORATORY (SWMCNL)

Improving farming systems' resilience to the impact of climate change

The Soil and Water Management and Crop Nutrition Laboratory assists Member States to use nuclear technologies, through the development of robust and affordable isotope and nuclear techniques to improve soil, water and nutrient management practices that support the development of climate-smart agriculture and contribute to reducing greenhouse gas emissions from farmlands. The application of isotopic and nuclear techniques has gradually advanced from a field scale to an area-wide scale. New, robust and affordable isotope and nuclear techniques now enable field staff to effectively measure real-time changes in soil and water quantity and quality and therefore improved practices that make farming systems more resilient to the impacts of climate change.

Soil erosion assessment and control

The SWMCNL applies fallout radionuclide techniques to assess the magnitude of soil erosion and the impact of soil conservation measures on soil erosion. This then allows Member States to develop strategies for sustainable agriculture and to minimize land degradation. Recently, compound-specific stable isotope techniques have been developed and adopted to identify sediments sources and to apportion their contributions from different land uses on an area-wide scale. They also assist land managers and farmers by providing guidelines to improve land management practices for sustainable agriculture.

Agricultural water management

Using nuclear techniques, the Laboratory helps Member States optimize water conservation in agricultural landscapes through the use of farm ponds and wetlands. The SWMCNL also assists Member States in assessing the performance of different irrigation water management technologies, and in determining crop water requirements to increase crop water productivity and area-wide water use efficiency.

Enhancing nuclear emergency response in food and agriculture

Recent nuclear incidents and the consequent increase in demand from Member States for assistance in this area, has directed the focus of the Laboratory towards rapid and real-time responses to nuclear emergencies affecting food and agriculture, including soil and agricultural water resources. The SWMCNL supports the critical need of Member States to improve data collection and the management and mapping (visualization) necessary for the effective and timely dissemination and communication of information to stakeholders in affected areas. It also develops technologies to assess the effects of such incidences on soil, food and agricultural produce. In association with global partners, the SWMCNL is developing tools to record and map (visualize) the effects of nuclear incidences in agricultural landscapes.

From Lab to Field

Stories of Success in Facts and Figures

The Joint FAO/IAEA Laboratories – building on the success of the FAO/IAEA partnership – help countries to develop the capacity to optimize the use of nuclear and related technologies for food and agricultural development. Here are some facts and figures to illustrate the impact of this work from the lab to the field:

111 countries

requesting and receiving one or more services from at least one of the FAO/IAEA Agriculture and Biotechnology Laboratories in 2012-2013,

reflecting the importance of these services to Member States and an indication of their unique alignment with the food and agricultural issues faced by the concerned countries. Sixty-one countries received such services from two or more laboratories.

500 research institutes and experimental stations in Member States

networking and increasing their R&D capacity as a result of coordinated research projects managed by the FAO/IAEA partnership, making it one of the largest collaborative agricultural research networks worldwide.

75 countries using animal disease diagnostic techniques developed or validated by the APHL to support the prevention, control and eradication of animal diseases, such as foot-and-mouth disease, African swine fever, avian influenza and Rift Valley fever. These diagnostic tools are used in conjunction with other control measures in the worldwide health programmes of World Health Organization (WHO), World Animal Health Organisation (OIE), Consultative Group of International Agricultural Research and other FAO divisions. For example, during the recent outbreak of avian influenza in China, the APHL played an important role in improving diagnostic capacities in more than 32 countries in Asia and Eastern Europe through targeted training courses, technology transfer and technical support.

national veterinary diagnostic institutes and laboratories working together for the control of transboundary animal diseases within the VETLAB Network, a network initially developed and supported by APHL during the global rinderpest eradication campaign to transfer and support developed and validated technologies. The VETLAB network has become a critical component of APHL for the sustainable transfer of technologies, improvements in laboratory infrastructure and staff proficiency, and the provision of methodological and operational guidance.

125 methods for analysing food validated by FEPL in 2012-2013, and in the same period, over 206 laboratory personnel from Member States were trained in analytical procedures. These activities help Member States reliably monitor veterinary drug, pesticide, heavy metal and mycotoxin residues and contaminants. The methods produced at FEPL are made freely available using the internet as a platform and are shared through the Joint FAO/IAEA database on Food Contaminant Residue Information System.

1.5 BILLION US Dollars

in estimated economic losses per year if the Mediterranean fruit fly were to become permanently established in California. The California Department of Food and Agriculture said there would also be a dramatic increase of insecticide use, amounting to 1.4-1.7 million pounds of active ingredient annually. The preventive release of irradiated and sterile male Mediterranean fruit flies, a strain developed by IPCL, is a crucial part of maintaining California's Mediterranean fruit-fly-free status, thereby protecting its large horticultural industries and environment. Similar preventive sterile male releases have been performed in Florida and Texas as well as outside of the USA.

32 institutes

from 23 different countries working with FEPL in developing and/or implementing technology packages to enable systems for food traceability. This new initiative in FEPL is to develop and refine nuclear and related technologies for the analysis of food in order to authenticate it and/or trace its geographical origin. Food fraud is estimated to cost the global food industry US $10-15 billion per year, affecting approximately 10 per cent of all commercially sold products. Effective traceability systems are also essential to deal with food safety incidents caused by unintentionally mislabelled or contaminated foods.

2.8Million US DOLLARS PER YEAR

in additional revenue to small-scale farmers in the Niayes in Senegal following the eradication of the tsetse fly from the region. A pest control campaign initiated in 2009 reduced the fly population by more than 99% in 80% of the target areas and paved the way for its complete eradication using SIT. The logistics support and tsetse SIT provided by the IPCL was crucial to the success of the programme.

300M US Dollars

the annual additional income to farmers in Viet Nam's Mekong Delta following the introduction of the high-quality, salinity-tolerant mutant rice variety VND95-20. The variety became a key export variety in 2005 when it covered 30% of the rice-growing areas in the Mekong Delta. The Viet Nam counterpart of this project received the National Prize of Science and Technology of Viet Nam for the achievement. The mutation breeding technology developed at the PBGL was crucial to the success of the project.

1.2 BILLION US DOLLARS

the estimated annual loss caused by the devastating Ug99 black stem rust, a wheat disease that causes 80-100% crop failure and threatens global wheat production. A particularly successful and high-impact example of mutation breeding was the release in 2014 of two mutant wheat varieties in Kenya resistant to Ug99. The pioneering research of the PBGL on crop mutation breeding was crucial to this project.

60 countries

are using fallout radionuclide techniques that have been significantly improved by the SWMCNL. To assess the magnitude of soil erosion, the countries are using CRPs so that appropriate soil and water conservation management practices can be effectively targeted to combat the problems. On the hill slopes of the Pamir Mountains in Tajikistan, the use of fallout radionuclide technologies developed at the SWMCNL helped to determine the extent of soil erosion and to design remedial actions to effectively control soil erosion and reduce the loss of fertile soil.

65 national agricultural research institutes

and extension services in developing countries use isotope techniques to quantify the nitrogen fixation potential of grain and forage legumes under a range of cropping systems and agro-climatic conditions, which have the potential to fix some 33 million tonnes of atmospheric nitrogen each year. The SWMCNL has helped to make biological nitrogen fixation a cornerstone of today's soil fertility, quality and nutrient management systems, supplementing the use of chemical fertilizers worth billions of dollars.

3218 induced mutant crop varieties

have been officially released to farmers for production, with most generated using mutation induction technologies developed and supported by the PBGL. A particularly successful and high-impact example of mutation breeding supported by the PBGL was the release of the 'Centenario II' barley mutant variety in Peru that can be grown in the Andes at altitudes above 3000 meters where other barley varieties fail. Using this improved variety, the Andean subsistence farmers now produce enough grain to both meet local family needs and to generate additional revenue by selling processed flour.

Game-Changing Technologies

The Joint FAO/IAEA Laboratories, leveraging the strong FAO/IAEA partnership, continually strive to be at the forefront in the development of game-changing nuclear and related technologies that contribute to the world's food and agricultural development. Some of the most pertinent game-changing technologies developed by these Laboratories during the past fifty years include:

Crop Production

1. Techniques using isotopes to optimize the uptake of water and nutrients by plants.
2. Stable isotope techniques to help quantify and make biological nitrogen fixation a cornerstone of today's soil fertility management systems.
3. Plant breeding methods using radiation to develop crop varieties that produce higher yields or that can thrive in harsh climates.
4. *In vitro* tissue culture that facilitates rapid mutation breeding also in vegetatively propagated crops.

Agricultural Pest Control

5. Development and application of the sterile insect technique to suppress or eradicate major insect pests threatening crops and livestock. The technique especially targets pests that cause significant losses, affect international trade or transmit human and animal diseases.
6. Sterile insect technique and the related inherited sterility approaches have proven especially effective against several fruit fly pests, including the Mediterranean fruit fly, various moth pests and different species of tsetse and screwworm flies.
7. *In vitro* blood feeding methods, mass-rearing systems and genetic sexing mechanisms that improve the sterile insect technique and significantly reduce the cost of rearing sterile insects for release.

Animal Health and Productivity

8. Highly sensitive techniques that improve the breeding efficiency of artificial insemination in ruminants.

9. Immunological and molecular techniques that rapidly identify damaging diseases such as foot-and-mouth disease, brucellosis, African swine fever, peste des petits ruminants and Rift Valley fever.

Environmental Protection

10. Techniques using isotopes that minimize land degradation and water pollution, and improve soil fertility.

11. Applications using radionuclides that identify cost-effective practices to reduce soil erosion and advance the understanding of factors causing it.

12. Nuclear techniques that identify the potential to increase agricultural water use efficiency.

Food Safety

13. Methods that utilize radiation to improve food by destroying bacteria, insects and other organisms that cause spoilage or human diseases.

14. Validated methods of sampling and analysis to trace, detect, monitor and control food contamination.

15. Stable isotopic and complimentary techniques developed to assist in the detection of food fraud.

Future Direction

The major global trends that will frame future agricultural development are likely to be rising food demand, lingering food insecurity, growing scarcities of natural resources and the impact of climate change. Their impact will be evident in all countries, but will most strongly be felt in developing nations, either because they will be more affected by these changes or because their ability to cope with these challenges is more limited. After decades of stagnation in public investment in agricultural research, and with science and technology progressively becoming a private good, national agricultural research systems in most developing countries are weak and ill-prepared to deal with these huge challenges and often face huge gaps in research and development (R&D) activities and research capacity.

Future global challenges will further increase the demand for appropriate and highly targeted agricultural research and development solutions. In support of FAO's vision of "a world free from hunger and malnutrition where food and agriculture contribute to improving the living standards of all, especially the poorest, in an economically, socially and environmentally sustainable manner", and the vision of the IAEA embodied in "Atoms for Peace", the FAO/IAEA Laboratories will play a leading role. They will contribute to reducing poverty, hunger and malnutrition in the world by using nuclear and related technologies wherever these can play a unique or competitive role. To do so, the FAO/IAEA Laboratories will focus on demand-driven, applied research activities that achieve clearly defined goals in food security; strengthen partnerships with agricultural research institutions at the global, regional and country level; and increase institutional capacity building and technology transfer in FAO and IAEA Member States.

While the future activities of the FAO/IAEA Laboratories will continue to focus on improving the sustainable intensification of agricultural productivity and ensuring food safety and quality, their future direction will also encompass climate-smart agriculture to ensure better adaptation to and mitigation of climate change in global agriculture. They are also committed to contributing to the control of emerging transboundary animal and plant pests and diseases; to increasing the resilience of livelihoods to threats and crises in agriculture; and to developing more inclusive and efficient agricultural and food systems and protecting human lives.

"The FAO/IAEA Seibersdorf Laboratory is an excellent cooperative partner of CGIAR centers in food and agriculture."

— Former Director of the Consultative Group on International Agricultural Research (CGIAR)

"The FAO/IAEA Seibersdorf Laboratory is a global training centre for developing countries."

— Agriculture Minister of Mongolia

The Seibersdorf Laboratory benefits not only developing countries but all Member States.

— Ambassadors from EU countries

"The FAO/IAEA Seibersdorf Laboratory is the world's SIT university."

— Senior official from the United States Department of Agriculture (USDA)

"The FAO/IAEA Seibersdorf Laboratory is the world's reference laboratory in many areas of nuclear applications in agriculture."

— Minister of Energy from South Africa

"The FAO/IAEA Seibersdorf Laboratory is the world center of nuclear applications in food and agriculture."

— President of the Chinese Academy of Agricultural Sciences

IAEA

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