IAEA

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Building better agriculture
one atom at a time

Nuclear technology:
a tool for improving agricultural production

IN A WORLD FACING the double dilemma of exponential population growth and changing climates, nuclear technology offers safe avenues to solve production problems, protect soil and water resources and conserve biodiversity which, in turn, means increased hope for global food security. Application of nuclear technology has a proven record in increasing agricultural production. Higher and more reliable yields not only improve farmers' livelihoods, they mean better quality and safer food for consumers.

The methods used vary – isotope measurements identify and trace the efficiency of crop inputs and animal feeds, gamma rays sterilize male insects so when they return to the wild they are unable to produce progeny, irradiation stops the growth of pests and expands the shelf life of grains, spices and processed foods, radiation-induced mutation speeds up natural genetic changes in crops to support plant breeders, and genetic markers expedite the identification of animal diseases so treatment begins more effectively. All of these methods, plus a host of others that come under the heading of "nuclear technology" are invaluable tools for agriculture and food production.

For almost five decades, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture has guided development of new nuclear-based methodologies requested by its Member Countries and facilitated their adaptation, adoption and application. A harbinger of the UN's Delivering as One, the Joint FAO/IAEA Division stands as the UN system's only joint venture and the only UN programme that operates its own laboratories.

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Nuclear technology makes a powerful and critical contribution to improving agricultural production and food security. Using cutting-edge, value-adding nuclear applications provides modern and efficient avenues for addressing agricultural problems. The Joint FAO/IAEA Division focuses its work on developing and applying nuclear technologies through its five subprogrammes and laboratory activities.

Soil and Water Management & Crop Nutrition: isotopic and radiation methods measure and monitor nutrients and water in the soil-crop system as the basis for strategies to ensure best results through judicious and efficient use of resources.

Plant Breeding and Genetics: radiation creates variability in desired traits of food and industrial crops and is used to speed breeding of varieties that have higher yields and improved resistance to disease and to environmental stresses such as drought and salinity.

Animal Production and Health: isotopes are used to develop diets and feeding strategies that improve productivity and reproductive efficiency while immunoassay methods help diagnose diseases and monitor effectiveness of disease control and eradication programmes.

Insect Pest Control: sterile insect techniques offer an alternative means of suppressing and, in some cases, even eradicating insects such as fruit flies, tsetse flies, moths and malaria-carrying mosquitoes.

Food Safety and Control: irradiation provides a safe and environmentally friendly method for controlling food-borne diseases and insect pests; other nuclear technologies are used to trace and authenticate food products and to detect, monitor and track the fate of contaminants in foods and the environment.

FAO/IAEA Agriculture & Biotechnology Laboratories: laboratory R&D, technical services and laboratory training activities support the development and transfer of new technologies and their adaptation to local needs and environments.

The Joint FAO/IAEA Division

combines the global goals of the Food and Agriculture Organization of the United Nations

- reduction of the absolute number of people suffering from hunger, progressively ensuring a world in which all people at all times have sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life
- elimination of poverty and the driving forward of economic and social progress for all with increased food production, enhanced rural development and sustainable livelihoods
- sustainable management and utilisation of natural resources, including land, water, air, climate and genetic resources, for the benefit of present and future generations

with the goal of the International Atomic Energy Agency

- mobilize peaceful applications of nuclear science and technology for critical needs in developing countries

and all of humanity benefits.

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

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Imagine...

- *Barley growing at 5000 meters above sea level, rice growing in salty soils*
- *Immune suppressed patients eating ice cream without fear of infections*
- *Farmers cutting back on irrigation and fertilizer while improving crop yields*
- *Herders rearing animals in areas freed of the dreaded rinderpest disease*
- *Citrus growers increasing their exports and their incomes*

Different scenes, different parts of the world, but they are connected – connected through nuclear technology. In each case, cutting-edge nuclear technologies have added value to traditional farming and food systems by making it possible to ...

- *Speed the genetic development of robust new crop varieties*
- *Control pathogen growth in grains and processed foods*
- *Trace a crop's uptake of water and sequestering of nitrogen*
- *Diagnose and treat animal diseases and maintain surveillance*
- *Control the presence of harmful pests in high cropping areas*

IAEA and FAO – a strategic partnership connects and delivers

ATOMIC ENERGY AND AGRICULTURE – seemingly at opposite ends of any development spectrum, but in reality, linking third millennium nuclear technology with the traditions of conventional agriculture has proven an extremely valuable and unique collaboration in agricultural research and development. The decision to establish a joint division combining the IAEA's nuclear methodologies with FAO's food and agriculture expertise was nothing if not visionary for its time, offering an alternative use for atomic power originally called Atoms for Peace. The year was 1964. FAO had its own atomic energy branch, IAEA had its agriculture unit – thus, the Joint IAEA/FAO Division of Nuclear Techniques in Food and Agriculture created a common programme that avoided overlap and duplication of efforts.

Now known as the Joint Division, it can point to achievements that have made critical contributions to global efforts to combat hunger and attain food security. It operates with a staff of 100 scientists, technical experts and support personnel divided among offices and laboratories, an annual budget of approximately US$17.5 million plus an additional US$10–14 million in technical cooperation projects, all geared to helping Member States solve practical agricultural problems with nuclear technology. Its research and development activities are broken into five separate but interrelated areas:

- soil and water management and crop nutrition
- plant breeding and genetics
- animal production and health
- insect pest control
- food and safety and control.

In addition, the Joint Division has identified four avenues for adding value to its research and development, refered to as the four pillars:

- research coordination
- laboratory support
- capacity building
- information dissemination.

Recognizing that even the mention of the term "nuclear technology" can be intimidating to those not versed in the breadth of agricultural applications, this information packet introduces the work of the five research and development divisions, identifies the methodologies and activities underway in each one, and quantifies the current successes of these activities. The hope is to demystify the role of nuclear technology in agriculture and raise awareness of the crucial need for harnessing the potential that this technology has to offer.

Joint FAO/IAEA Division Mission

To strengthen capacity for using nuclear and related methods to improve technologies for food security and sustainable agriculture, and to disseminate these through international cooperation in research, training and other outreach activities of Member States of FAO and IAEA.

ADDING VALUE:

Pillars of the Joint FAO/IAEA Division increase the impact of R&D

Research coordination

THE JOINT FAO/IAEA DIVISION'S efforts to help Member States adapt to the rapidly changing landscape of agriculture rely on the expertise of IAEA and FAO but also seeks the input of experts from the global agricultural community including both developed and developing countries, NGOs and civil society. When Member States seek help in finding practical solutions to problems they are unable to solve on their own, the Joint Division identifies the type of expertise needed for the solution and invites appropriate experts and institutions to join a Coordinated Research Project. The participants pool knowledge and work with the countries to design and undertake the necessary research. Institutes in developing countries are usually awarded research contracts with some level of financial support while institutes in developed countries participate with research agreements and receive financial support only for attending research coordination meetings. Each year, there are some 30–40 Coordinated Research Projects underway, involving some 600 research institutions and experimental stations. Participants work individually but come together for meetings as needed throughout the life of the project. These projects normally last for five years and results are published.

Technical support

SITUATED 35 KILOMETERS south of the IAEA Vienna headquarters, the FAO/IAEA Agriculture & Biotechnology Laboratories add a critical practical problem-solving element to the work of the Joint Division. Here, scientists and technicians have the unique opportunity to put their theories into practice in order to develop or fine-tune methodologies tailored to the needs of developing countries. Lab results can be tested in the fields that surround the lab complex and then spread through application in field projects. This is the kind of applied research that developing countries could never afford to do on their own nor would they have the expertise. Thus, in addition to providing the lab facilities and expertise for applied research activities, the laboratory support arm of the Joint Division also provides training to scientists and coordinates with donors to sponsor fellowships. This enables scientists from both developed and developing countries to coordinate research and work together – all aimed at ensuring that the knowhow is there to continue the work at the national level. Above all, this work links the lab to the farmer. A further bridge is made through the support of FAO and IAEA Technical Cooperation Projects that transfer technology to developing country Member States.

The Joint Division provides another important level of technical support through its evaluation, standardization and selection of appropriate equipment for each specific project or need. Any equipment supplied for use in developing countries must be simple, robust and easily repaired, and work within the local infrastructure and conditions. This has important advantages in that Joint Division technical staff members, scientists and fellows who are responsible for implementing the projects acquire experience in the routine operation, maintenance and even repair of commonly used equipment. Supplies of frequently required spare parts also can be purchased in bulk and held for quick dispatch to field projects when required.

Capacity building

ABOUT 50 TRAINING COURSES, workshops, and seminars are held annually at the Joint FAO/IAEA Division, involving more than 500 trainees, with the overall goal of building the capacity of Member States. As well-trained personnel are essential to the success and sustainability of any endeavour, training is an important, if not the most important component of activities supported by the Joint Division.

Far too often, the long-term training provided by institutes in the developed world is not sufficiently relevant to the needs of scientists from developing countries. IAEA fellowships usually extend no more than six months, and while importance is given to training in technology, every effort is made to ensure that equal emphasis is given to the wider aspects of the problem to be studied or solved. For example, in the courses, trainees learn nuclear techniques but also conventional techniques so they recognize the links. They receive intensive hands-on experience in laboratory analyses and also undertake field work. Most training also includes training-of-trainer elements, so the training will have a cascade effect.

Regional as well as interregional training courses are held periodically to train young scientists in developing countries in the technologies associated with the application of immunoassay techniques. In general, these last four to six weeks and provide participants with the basic theoretical knowledge and practical skills necessary to initiate studies aimed at solving agricultural problems in their own countries. The courses are not just held for technicians and scientists. They are also held for policy-makers from developing countries who receive training that will be helpful in development of legislation or guidelines in the agriculture sector. At the end of the training, the participants remain connected via electronic networks that they set up themselves so they can continue to communicate with each other and with their trainers.


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Information dissemination

INFORMATION DISSEMINATION adds a critical layer to the work of the Joint FAO/IAEA Division, by taking the data that is gathered, the decisions that are taken, and the ideas that emerge from discussions out of the meeting rooms and laboratories and to the widest audience possible. The Joint Division publishes a host of materials, ranging from the reports of meetings and seminars to results of the CRPs, as well as books, manuals and booklets that support the ongoing work.

Twice a year, each of the five sections publishes a newsletter that contains information on forthcoming events, reports on events that have been held, and gives a rundown of projects that are underway.

The information dissemination pillar goes further than traditional publications for sharing knowledge. It also sets up opportunities for knowledge-sharing missions. For example, a group of Brazilian fellows who received training at the Joint Division's laboratory in how to improve their own technology in Brazil then passed on what they learned to other technicians in Africa. The goal is to enable Member States to take advantage of this possibility to generate and share knowledge.

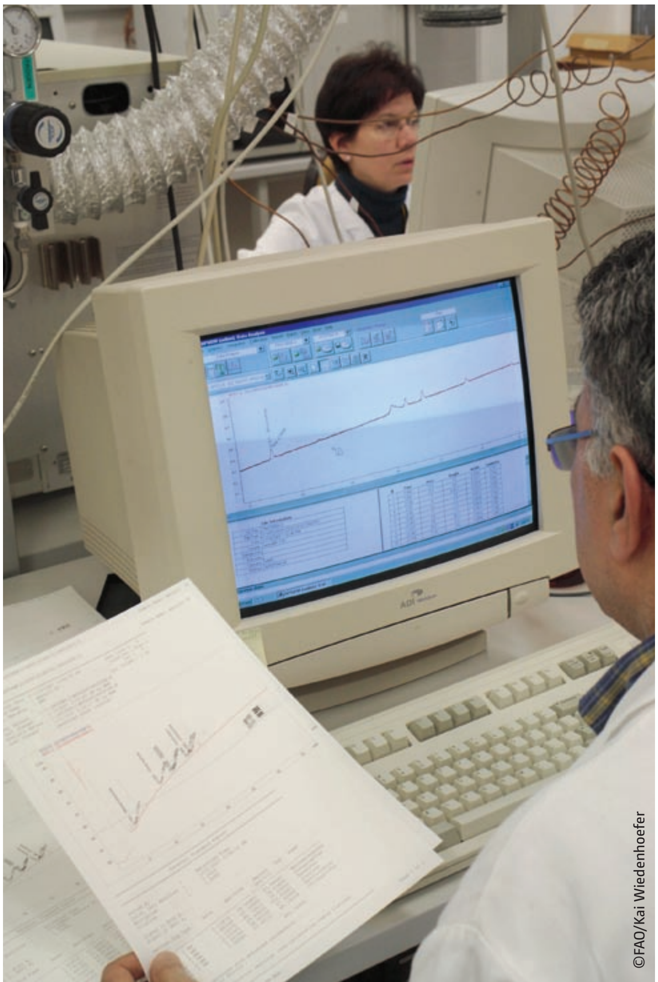
Food Traceability Systems

Nuclear techniques add science to the paper trail

AS GLOBAL FOOD TRADE continues to expand, the ability to trace food back to its origin and establish proof of provenance and authenticity takes an increasingly important role in the context of food safety, food quality and consumer protection. Currently, the industry relies on a "paper trail" but the use of isotopic applications adds a new level of science to the system.

Having a more scientific food tracing system in place means ensuring consumers that the package of "basmati rice" they purchase is the real aromatic and flavourful rice grown from cultivars that originated in India and Pakistan. It also means that if a market is hit by an outbreak of food poisoning, it is not necessary to make blanket recalls from supermarket shelves. The contamination can be traced directly back to the specific producer.

Traceability systems that enable provenance of food to be determined can provide an independent means of proving authenticity, combating fraudulent practices and controlling adulteration, which are important for economic, religious or cultural reasons. Even food that is safe for human consumption may have animal or botanical sources that render it unfit for consumers to eat. For example, consumers who follow Halal practices need assurance that any gelatin used in a processed food is not derived from pork sources or that ethanol is not derived from wines or spirits.



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Confirming food origins to protect consumers

The application of nuclear technologies – such as identifying food products through genomic techniques and isotopic fingerprinting – can provide an independent means of verifying the traditional "paper" traceability systems. Genomic techniques can easily confirm that a product labelled as basmati rice is of the correct cultivar, and isotopic and elemental fingerprinting can confirm that it originated in the basmati rice growing region of India and Pakistan. The same isotopic techniques can be used to trace the origin of contaminants in foods and help to prevent their reoccurrence. These are cutting edge tools that have the potential to be applied in many developing countries, enhancing their capacities to improve food safety and quality.

In order to support its Member States in increasing their capacities to establish and maintain traceability systems for their food industries, the Joint FAO/IAEA Division has developed a Coordinated Research Project for

"Implementation of Nuclear Techniques to Improve Food Traceability", specifically designed to:

- help laboratories in developing countries implement sustainable analytical tools that permit independent verification of paper-based traceability systems for food commodities, and
- enable regulatory authorities to trace contaminated foods back to their source.

Further, raising consumer awareness of the existence of these tools and protocols for determining product origin would act as a deterrent to traders who knowingly re-export contaminated products.

Coordinating research to ensure the application of appropriate methods

The Joint FAO/IAEA Division has some five decades of experience working with developing countries in the application of nuclear technology to food and agriculture. It is well aware of the levels of capacity building and training needed to support food laboratories in establishing food control systems and is committed to developing analytical methods that do not require the purchase of costly equipment.

In general, helping countries establish food traceability systems that will be affordable and accessible requires:

- implementation of existing and emerging analytical techniques to verify the traceability of food commodities in response to food safety incidents and in accordance with national and international regulations and trade requirements,
- development of a sustainable database of isotopic composition and elemental concentrations obtained from authentic samples,
- development of a robust modeling system that enables Member States to use their own data for interpretation of origin and verification of paper traceability or labeling claims.

Once these have been established, the countries can focus on developing harmonized techniques for determining food provenance and authenticity, including:

- developing standard operating procedures, including quality assurance and quality control, and harmonized protocols for food traceability, based on nuclear and complementary techniques,
- prioritizing food commodities produced in developing countries that are targeted for isotopic and elemental characterization,
- establishing a database of isotopic and elemental reference measurement results based on a collection of food samples with guaranteed authenticity,
- creating a data base, hosted by the IAEA and linked to other databases, that is accessible to partners for use in traceability studies,
- building a toolbox of multivariate statistical methods, such as protocols for the interpretation of data,
- building a Web-based tool that can estimate the isotopic and elemental composition of selected foodstuffs at defined geographical locations.

Joint FAO/IAEA Programme
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Fruit fly birth control

Sterile insect technique improves yields, nutrition, income and trade

UNTIL RECENTLY, FRUIT FLIES in a 38 000 ha area of southern Peru caused annual production losses of US$12 million. Now, through the integrated application of a technique that uses ionizing radiation to sterilize large numbers of the insects, the area is free of the pests. This sterile insect technique (SIT) has meant improved incomes for 18 000 producers, safe and better quality food for trade, and has eliminated the annual use of 600 000 litres of pesticides.

The SIT, often referred to as a form of “birth control for insects”, has been applied successfully against a range of devastating fruit flies – insects that have a greater impact on world trade in agricultural products than almost any other pest. They attack fruits and vegetables, reducing local consumption of healthy fruits and vegetables and causing major economic losses in a majority of horticultural crops. Their economic consequences are so great that countries free of the major fruit fly species prohibit the import of fresh produce from countries where these pests are endemic or have been introduced, which can include both tropical and temperate countries in the developing world.

Tropical and temperate countries are well situated to export fruits and vegetables but, because importing countries refuse to take products from countries with fruit flies, they pose a significant barrier to trade. It is a vicious cycle – when importing countries ban the products, exporting countries stop growing them because they would have no market because of the international restrictions.

The SIT: how it works

A pest control measure recognized since the 1950s, SIT meets the demand for environmentally friendly, consumer safe pest control. The control takes place through a series of steps:

- specialized factories produce large numbers of the target fruit fly,
- pupae are sterilized by a specific dose of gamma or X ray radiation and the flies are sequentially released into the field in sufficient numbers to achieve appropriate sterile-to-wild insect ratios,
- sterile males find and mate with wild females, transferring their non-viable sperm.

As a result, there are no offspring, which causes a continuous reduction in the natural pest population.

Jesus Reyes

However, the integrated application of the SIT to develop low prevalence or pest-free areas can break the cycle. When exporting countries and the private sector see that the pest can be suppressed and the product accepted by importers, then they will invest in developing a competitive horticultural industry. Thus, the creation of low prevalence and fly-free areas with the SIT helps countries overcome trade barriers.

The SIT offers targeted, consumer-safe and environmentally friendly pest control

Fruit flies can be controlled through intensive insecticide applications, but those applications also kill the natural enemies of other pests in the field and can result in secondary pest outbreaks. They also kill non-targeted organisms such as pollinators and other beneficial insects. In addition, food safety concerns are compelling agricultural producers to decrease insecticide residue levels to meet import restrictions and international standards. Both consumers and authorities are increasingly aware of the environmental cost of large-scale application of insecticides and are demanding environmentally friendlier pest control methods.

Area-wide approach needed. Fruit flies and other pests do not stop at orchard, provincial or national borders.

Therefore, to be effective, the SIT needs to be applied as part of an area-wide integrated pest management (AW-IPM) approach. For example, the SIT programme in southern Peru mentioned earlier was part of a larger operation to expand the fruit fly-free area in Chile. Guatemala releases 2.5 billion sterilized fruit flies a week, as part of a programme to contain the pest to protect the fruit and vegetable industries of Guatemala, Mexico, Belize and the United States. The validity of this approach also has been demonstrated in Argentina, Australia, Brazil, Chile, Israel, Japan, Jordan, Mexico, Morocco, Peru, Portugal, South Africa, Spain, Thailand, and the United States, and is under development in other countries. The SIT has been applied successfully against a range of devastating fruit fly pests of economic and quarantine importance such as the Mediterranean (medfly), Caribbean, melon, Mexican, Oriental, Queensland, South American and West Indian fruit flies.

Irradiation means safer pest control. As every single fruit fly must be sterilized before release, irradiation remains a central and indispensable part of the total process and also gives the SIT an advantage over conventional pesticide control methods because it is:

- inherently safe and responds to demands to protect the environment and human health,
- species specific and has no detrimental effect on beneficial non-target organisms,
- uniquely effective in eradicating outbreaks of invasive pest species.

Passing on improved techniques through research and training. Applied research undertaken at the Insect Pest Control Laboratory (IPCL) of the FAO/IAEA Agriculture and Biotechnology Laboratories in Seibersdorf, Austria, addresses technical gaps in relation to fruit fly mass rearing, sterilization, quality control, behaviour and genetics. The IPCL is also a reference centre for insect strains and mutants, provides training to fellows from Member States in areas such as the development and use of equipment, hosts consultants and visiting scientists, supplies biological materials, and offers expert support for research and field operational projects.

Jordan and Israel cooperate on SIT control programme

The Mediterranean fruit fly is being successfully suppressed in the Arava/Araba Valley situated on both sides of the border between the Hashemite Kingdom of Jordan and the State of Israel using a transboundary control approach that includes the SIT. The project has culminated in the yearly exports of Mediterranean fruit fly-free commodities worth some US$150 million.

Behaviour and genetic studies contribute to environmentally friendly Mediterranean fruit fly control

Mediterranean fruit fly mating is a female-driven process in which a group of courting males “dance” for a female and she chooses her mate. Thus it is critical that the sterile males behave normally and are not physically damaged by the irradiation process. Genetic sexing allows the elimination of females at the egg stage, thus improving the cost-effectiveness of the SIT since only males need to be mass reared and irradiated.

Member States benefit from Joint FAO/IAEA Division support

The successful use of the SIT is mostly driven by governments in active partnerships with the private sector and other national and international organizations that share a common vision. Aligning well-organized fruit and vegetable producers with government initiatives to improve local access to safe horticultural products and to facilitate exports is key for success.

The Joint FAO/IAEA Division provides technical support to Member States for SIT projects, including advice on establishing the physical infrastructure required to implement the SIT and promoting sustainable cooperation avenues. For area-wide IPM projects that include an SIT component, the Joint Division also provides development and implementation assistance in the form of strategic and applied research, technology transfer, capacity building, policy advice and information management. It also promotes the development and application of phytosanitary standards which facilitate international trade of fresh fruit and vegetables grown in low prevalence and fly-free areas.

For further information, please visit:
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Suppressing moth pests

Inherited sterility technique insures male moths are born sterile

MOTHS ARE AMONG the most feared invasive insect pest species. They are the major damaging pests of annual and perennial fibre and food crops, forest products and stored food commodities throughout the world. The damage inflicted to the fibre and food commodities attacked can be up to 80 percent of yields.

Traditionally, moth pests have been controlled through intensive insecticide applications. However, these broad applications have negative add-on effects because they also kill the natural predators of other pest populations, which can leave fields vulnerable to secondary pest outbreaks, and can kill non-targeted organisms such as pollinators and other beneficial insects. In addition, today's increasing consumer concerns about food safety and environmental costs are compelling agricultural producers to decrease insecticide residue levels to meet import restrictions and international standards.

Inherited sterility (IS) – a unique pest-control technique that uses radiation to introduce sterility in the target pest population through pest management campaigns – has proven both safe and successful for moth control.

Technique affects next-generation sterility

The IS technique was first tested in the 1960s against codling moths which attack apples, but is now routinely applied to many other moth species of economic importance. With IS, specialized factories produce large numbers of the target moth pest, treat them with a specific "sub-sterilizing" dose of gamma or X ray radiation, and sequentially release them into the field.

Sub-sterilizing dose. As the term "inherited" sterility implies, the radiation dose is kept at a sub-sterilizing level to ensure that the treated insects released in the field remain viable for mating. However, the dose of radiation they receive ensures that they will produce fewer offspring in the first generation, most of whom will be males and completely sterile. As a result, continuous release of sub-sterile moths will result in a gradual reduction in the natural moth pest population.

Area-wide IPM approach. IS plays a major role in controlling moth pests that attack commercial commodities and ornamental plants. However, because of the migratory nature of moths, IS cannot be applied on an orchard-by-orchard or field-by-field basis. Success depends on its being applied as part of an area-wide integrated pest management approach using a suppression or eradication strategy against an entire pest population in a delimited area. The validity of this approach to suppressing or eradicating moth pests has been demonstrated in Canada, Mexico, New Zealand, South Africa and the United States and is under development in other countries.

Radiation remains key to IS success

The use of ionizing radiation to irradiate large numbers of insects is the key to IS. There is no acceptable alternative that could replace radiation-induced sterility in this process. As every single moth must be treated with a sub-sterilizing dose before release, irradiation remains a central and indispensable part of the total process.

When compared with conventional pest control, the advantages of the IS application are numerous. Unlike insecticides which affect human health and biodiversity, the IS application is:

- inherently safe and responds to increasing demands to protect the environment and human health,

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- species specific, with no detrimental effect on beneficial non-target organisms, and
- uniquely effective in eradicating outbreaks of invasive pest species.

IS overcomes pest resistance to insecticides

IS has been applied successfully against a range of devastating moth pests of economic, environmental and quarantine importance such as the pink bollworm, codling moth, false codling moth, cactus moth and the Australian painted apple moth.

Control of most moth pests has been hampered by their increased resistance to most of the commonly used broad-spectrum insecticides. Hence, there is considerable potential for expanding IS applications to other moth pests, such as the date moth, European corn borer, Asian corn borer, Asian rice stem borer, cabbage webworm, Oriental fruit moth, sugarcane borer, corn earworm, diamond back moth and European grape vine moth.

The use of IS is mostly driven by governments in active partnerships with the private sector and other national and international organizations that share a common vision. Aligning well organized fruit and vegetable producers with government initiatives is key to achieving success.

Moth control: IS in action

Cactus moth, first detected in the United States (Florida) in 1989, expanded its range along the Gulf of Mexico. This invasive species feeds on prickly pear cacti, which have an economical and ecological importance, with many rare species that are part of the national biological patrimony of the USA and Mexico. In 2006, it invaded Isla Mujeres and Isla Contoy in Mexico. A bi-national Mexico-USA programme was established to eradicate the cactus moth from these islands and to contain its advance in the USA. Using releases of sub-sterile moths combined with infested host removal, the cactus moth was declared eradicated from the two Mexican islands in 2009.

False codling moth, a major citrus pest that has become resistant to most insecticides. After successful IS pilot projects, the South Africa government and its citrus industry co-launched a programme involving the building of a mass-rearing facility to produce sterile moths and the implementation of an area-wide suppression programme. Initially focussed on the important citrus-exporting region in the Western Cape, the programme has been so successful that this insecticide-free approach will be expanded to other citrus-producing provinces.

IS programmes benefit from research and training support

Through Cooperative Research Programmes, the Joint FAO/IAEA Division provides assistance to Member States in the development and implementation of area-wide integrated pest management projects that include IS components. In addition to the applied research and technology transfer, it provides capacity building, policy advice, and information management. It also promotes the development and application of phytosanitary standards, which facilitate international trade of fresh fruit and vegetables.
Member States benefit from the technical support of the Joint FAO/IAEA Division's Insect Pest Control Laboratory (IPCL) which conducts applied research in areas ranging from mass rearing and sterilization of insects to insect behaviour and genetics. It also maintains a reference centre for insect strains and mutants, and transfers technology by providing technical support and training, hosting consultants and visiting scientists for varying periods of time. To a lesser degree, it supplies basic materials and equipment, and training in the use of the equipment.

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Food irradiation

Helpful beams improve food safety and food quality

FROM CONTROLLING PESTS in shipments of grains to increasing the shelf life of packaged foods to adding more choices to the dinner trays of hospital patients, food irradiation contributes to improving both food safety and food quality. The irradiation process itself consists of shining beams of electrons, X-rays or gamma rays on food in order to destroy micro-organisms and control spoilage. In doing so, irradiation actually provides the same benefits as heat, refrigeration or chemical treatment with the added advantages that:

- it does not raise temperatures significantly, so food does not "cook",
- it does not affect taste, smell or texture of the food,
- it does not leave potentially harmful residues, unlike chemical treatments,
- it can be used to treat packaged foods, protecting them from subsequent microbial contamination or pest re-infestation.

In addition, irradiation can cut post-harvest food losses caused by insects, bacteria or mould, or by sprouting or over-ripening produce. These losses are estimated at between 25 and 40 percent of the harvest in many developing countries.

Food irradiation exposes food commodities to ionizing radiation under controlled conditions. Three major types of ionizing radiation are internationally recognized for the treatment of foods:

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Increasing the variety and ensuring the safety of hospital foods

Ensuring food safety is especially important for patients who have impaired immune systems. Irradiation technology can increase the variety, availability and acceptability of foods for HIV and AIDs patients or cancer patients undergoing chemotherapy who are immuno-compromised. Ordinarily, they would not be allowed to eat fresh produce (fruits, vegetables, salads), ready-to-eat meals (ethnic or locally produced) or feel-good foods such as ice cream because of fear of infection, but if it has been irradiated, it would be considered safe. A Coordinated Research Project on "Irradiated Foods for Immunocompromised Patients and other Potential Target Groups" will research and ultimately increase the range and variety of foods available for those with impaired immune systems (e.g. neutropenic patients) or patients who require other special foods, e.g. blended (nasogastric) hospital diets.

- gamma rays from the radionuclides cobalt-60 or caesium-137, and
- X-rays and electron beams generated from machine sources.

Irradiation does not completely sterilize food, but the many-fold reduction in micro-organisms helps prevent food poisoning while its ability to prevent sprouting and bacterial growth and to slow ripening reduces the waste that comes with spoilage. Also used as a quarantine treatment for insect pests, irradiation facilitates international trade of various fruits and vegetables by helping prevent the spread of insect pests of economic and environmental importance.

Irradiation for food security, safety and increasing food options

Although consumers benefit from globalization and the expanding opportunities and benefits of open markets, there are also risks associated with growing urbanization and increased international trade. For example, there is greater exposure to a variety of food safety hazards and increased potential for the spread of insect pests. Improving food safety and quality through the use of irradiation can mitigate these risks and enhance trade.

International conventions adopt irradiation treatments

The Joint FAO/IAEA Division's research activities led to the adoption of three phytosanitary irradiation treatments at the Fifth Meeting of the Commission on Phytosanitary Measures (CPM) of the International Plant Protection Convention (IPPC) in March 2010. These treatments are in addition to the eight irradiation treatments accepted by the IPPC in 2009, making a total of eleven internationally adopted post-harvest phytosanitary irradiation treatments for inclusion in the IPPC Standard No. 28 on Phytosanitary Treatments for Regulated Pests.

Food safety. Food irradiation can provide added value or alternatives to conventional food technologies. After many years of research and the development of international standards through the Joint FAO/WHO Codex Alimentarius Commission, more than 60 countries have regulations allowing the use of irradiation in at least one product. Though not widespread, the commercial use of food irradiation is growing.

Quarantine treatments. With increasing implementation of quarantine controls and the phasing out of traditional chemical fumigants used to treat agricultural products after harvest, it is anticipated that demands for plant health (phytosanitary) applications of food irradiation will increase. Irradiation is one of the few economically viable quarantine treatments that can be used in place of chemical treatments. Regulatory authorities and scientists from many internationally recognized institutions have studied research data on the effectiveness of irradiation as a quarantine treatment against a large range of insect pest species that infest various fruits and vegetables.

Treatment development for 29 insect species. The Joint FAO/IAEA Division has established a Coordinated Research Project (CRP), "Development of Generic Irradiation Doses for Quarantine Treatments", to support development of both generic and specific irradiation doses for pests and pest groups of quarantine importance for submission to the International Plant Protection Convention (IPPC) for adoption. The work covers 29 insect species from 13 arthropod families.

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Nuclear Techniques in Food and Agriculture

Making every drop count

Combating water crises through integrated soil and water management

EACH YEAR, farmers in developing countries use some 50–60 million tonnes of nitrogen as fertilizer. Yet, according to measurements made through the use of isotopes, less than half of that fertilizer actually reaches the crops.

When it comes to producing more crops from every drop of water by increasing water use efficiency, isotopic and nuclear techniques have an advantage over conventional techniques. They can be used as "tags" or "fingerprints" to identify how water and nutrients interact with soil components in crop and livestock production systems. They also can determine whether the water taken up by crops comes from rain, groundwater or irrigation, how it is best used by the plant and how much is actually needed for the crops to grow. This kind of information can guide farmers in making more efficient use of water and optimizing their irrigation scheduling.

Water use efficiency in agriculture. Agriculture is by far the largest global consumer of water, accounting for approximately 70 percent of freshwater withdrawn from lakes, waterways and aquifers around the world – a figure that is even higher in some developing countries and, with population growth, is projected to increase even more. This will put tremendous pressure on the agricultural sector to produce more food with less water.

Both rainfed and irrigated agriculture play important roles in meeting food demand, especially in developing countries, where some 60 percent of crop production is rainfed. Practically speaking, improving water use efficiency in agriculture requires improvements in:

- irrigation practices – in terms of the amount, time and frequency of applications, and
- irrigation technologies – including both drip and sprinkler irrigation.

Neutron probes allow safe use of brackish water for salt-tolerant crops

In Bangladesh, salinity affects approximately 2.9 million ha of the coastal region. Until recently, rice only could be grown immediately after the monsoon season, when rains had reduced soil salinity. Now, it is possible to schedule irrigation using brackish water by using neutron probes to measure soil moisture and the water requirements of salt-tolerant local crops (e.g. chickpeas, groundnuts and wheat) and set irrigation to levels that will not affect soil salinity. This has made year-round production possible for 0.9 million ha of agricultural land in the coastal regions of Bangladesh. In addition, these leguminous crops fix atmospheric nitrogen in the soil and, thus, provide nitrogen for subsequent rice production. As a result, farmers who had left the coastal region to seek employment in urban centres have returned, because they now have the potential for improved livelihoods.

Nuclear techniques guide irrigation management

In Libya and Turkey, farmers have increased potato tuber yields by more than 150 percent during the past five years while, at the same time, reducing the use of water and nitrogen fertilizer by more than 50 percent. The Joint FAO/IAEA Division has provided technical support to farmers in the form of improved information derived from measurements of isotope variations, which allowed them to switch from traditional sprinkler irrigation and soil applications of nitrogen fertilizer to the more efficient drip irrigation and fertigation. Farmers also saved considerable time, energy and labour costs. In the Nigde-Nevsehir Cappadocia Regions of Turkey, the new method meant an estimated savings of US$2 000 per ha and more than US$60 million in savings for the economy.

Integrating soil, water and nutrient management to optimize crop production

Looking to the future, the goal of agriculture is to ensure that every drop of water is used for crop growth – whether in irrigated or rainfed production systems. Thus, it is critical to optimize soil and nutrient management by developing integrated soil-water-nutrient management practices that minimize water waste and nutrient loss. For example, it is possible to provide the necessary nutrients for plant growth with appropriate applications of fertilizer and manure and by fixing atmospheric nitrogen in the soil with legume crops. These integrated practices not only minimize water waste and nutrient loss by avoiding runoff or deep drainage beyond the crop rooting zone, they also prevent the degradation of water quality and development of soil salinity. Minimum soil disturbance and the adequate

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return of crop residues and animal manure can increase soil organic matter and enhance soil quality and, in turn, improve plant nutrient supply and soil water retention.

Nuclear and isotopic techniques assess, design and monitor agricultural systems

The process for identifying the proportion of water taken up by a crop from different sources such as groundwater, irrigation or rainwater involves measuring the variation in the isotopic signatures of oxygen and hydrogen. This information can be used to develop strategies for optimization and conservation of the quantity and quality of water resources in agricultural landscapes.

Rainfed agriculture: improving crop water use. Water, carbon and nitrogen are the essential components of plant life and soil organic matter. Measurements of the isotopic signatures of carbon and nitrogen in soil components can be used to assess soil, water and nutrient management practices, the results can then be applied to improve their efficient use. The carbon isotopic composition of plant materials also can be used as an indicator of salinity and drought tolerance in crops.

Irrigated cropping systems: optimizing water use efficiency. Accurate soil water measurements are needed in order to target water application. By ensuring that water is used when and where it is most essential for optimal crop growth, it is possible to minimize loss of water and nutrients. Soil moisture neutron probes measure the interaction between radiation and soil water to provide an index of soil moisture status. This makes them ideal for measuring soil water content in salt-affected soils, as salinity reduces the accuracy of conventional soil water measurement devices that use soil electrical conductivity as an index of soil moisture content.

Isotopic techniques identify need for mulch in coffee plantations

In the Central Highlands of Vietnam, drought and water shortages affect production of the coffee plantations, which cover approximately 500 000 ha and provide the major livelihood. Isotopic techniques have been used to quantify water losses in coffee cultivation. Based on the results, management practices such as mulching with 5 cm of old branches and leaves have improved water use efficiency by 30 percent. This equates to 330 m3 of water per ha, and potentially saves 165 giga litres of water compared to non-covered ground.

Livestock production systems: focus on environment. Advances in water use efficiency and livestock productivity have had a positive effect on the environment. For example, there have been improvements in:

- local feeds, in terms of their quality, availability and ration formulation,
- livestock reproduction management and performance,
- genetic composition of local species and breeds, leading to higher production while also conserving the genetic characteristics that enable their adaptation to harsh environments and prevailing diseases.

Livestock produced in rain-fed grazing systems and/or fed on crop residues and agro-industrial by-products provide high quality animal protein for consumers without significantly affecting demand on water resources. Large numbers of grasses and leguminous pasture species have been evaluated and proven resistant to prolonged periods of dryness, to acid or saline soils, and to high altitude environments. They are currently being used as ruminant feed by farmers in developing countries.

For further information, please visit:
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International Atomic Energy Agency, *Wagramer Strasse 5, PO Box 100, 1400 Vienna, Austria*
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Rapid diagnosis

Nuclear applications reduce transboundary animal disease risks

GLOBAL CONSUMERS have become increasingly reliant on access to an adequate, high quality food supply and, at the same time, want assurance that their food has been produced in an environmentally safe, clean and ethical way. This has imposed new challenges on the veterinary and public health sectors which must find ways to improve livestock production in ways that are sustainable and affordable. The Joint FAO/IAEA Division has made significant contributions for the prevention, control or eradication of important livestock diseases by developing and validating serological and molecular diagnostic tools, using nuclear and nuclear-related techniques that can easily be transferred to countries in need.

Transboundary livestock diseases pose a major challenge to the production and distribution of animal products, particularly when they impact international trade. This is especially a problem today, as warming climates have allowed the spread of disease-carrying vectors into new areas. The Joint FAO/IAEA Division also supports the regional and global control programmes that are necessary for dealing with both animal diseases such as foot-and-mouth disease, African swine fever, contagious pleuro pneumonia, *peste de petits ruminants* and Newcastle disease, and those that can be transmitted to humans, such as brucellosis, tuberculosis, Rift Valley fever and avian influenza.

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Rinderpest “the cattle plague” eradicated

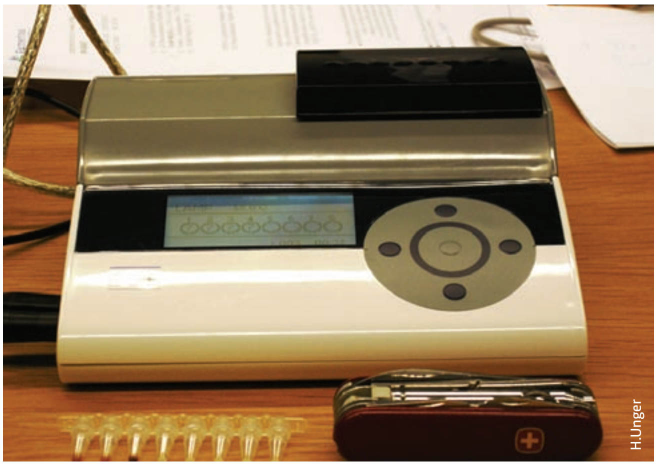
The Joint FAO/IAEA Division played a key role in one of the most successful veterinary control undertakings in history – the eradication of rinderpest, known since the days of the Roman Empire as the “cattle plague”. The Pan African Rinderpest campaign (PARC, 1986) and later on, the FAO Global Rinderpest Eradication Programme (GREP), focused on collaborative vaccination campaigns and on improving veterinary systems, setting up laboratory networks that allowed sharing of information about outbreaks and vaccination coverage. The Joint FAO/IAEA Division contributed to the campaign through the transfer of technologies, improvement of laboratory infrastructure and staff capacity building, and provided methodological and operational guidance, in collaboration with its global partners such as the European Union (EU) and African Union-Inter-African Bureau for Animal Resources (AU-IBAR).

Animal disease affects local production, national economies and global trade

Most developing countries would be capable of producing more meat, milk and eggs than they currently do if they could overcome limiting factors such as infectious diseases. These diminish animal productivity, damage animal populations and hinder international trade in animals and animal products, resulting in serious losses to smallholders and damage a country’s livestock sector and its economy.

Nuclear applications in diagnosis and treatment can lead to control and eradication

As was shown with the Rinderpest campaign, progressive control and eradication of transboundary diseases requires action at national and international levels. It is critical to



develop and apply suitable techniques and strategies for early and rapid disease diagnosis and surveillance, by implementing validated guidelines and standards in control programmes. The lack of rapid diagnostic systems normally results in an uncontrolled disease spread, affecting local and regional producers and substantially increases the expenses for control efforts such as vaccination and verification of the disease free status.

Immunoassays and molecular techniques. The latest generation of molecular diagnostic technologies offers unparalleled detection and discrimination methodologies which are vital for the sensitive detection and identification of pathogens. They are designed to allow a rapid and reliable diagnosis at the farm site, helping veterinary authorities, extension services and farmers to control and eradicate disease outbreaks that impair animal health and productivity.

- Nuclear and nuclear-related immunoassays and molecular techniques provide sensitive, robust, specific and rapid results, and offer significant advantages over conventional biological methods such as complement fixation tests or culture techniques and offer the possibility of point-of-care applications.

- Isotopes are used as markers to label protein and nucleic acid molecules, enabling specific and sensitive detection and characterization of harmful pathogens, as implemented in the polymerase chain reaction (PCR) which multiplies a single pathogen gene to millions of exact copies in a short time, allowing easy detection of only a few pathogens in a sick animal; and the enzyme-linked immuno-sorbent assays (ELISAs) that analyse serum to assess disease status through the rapid testing of thousands of samples at a time, which is vital in disease surveillance and for export certification.

Attenuated vaccines. Vaccination, one of humanity's greatest achievements, facilitates the eradication of serious, life-threatening diseases of both humans and animals. Apart from their efficacy in maintaining animal health and productivity, vaccines can have other significant impacts in a society that increasingly demands accountability from farmers and food processors as to the quality of their livestock products and their freedom from the contamination of drugs and chemicals. The Joint FAO/IAEA Division is working to develop new attenuated vaccines by using controlled doses of gamma irradiation against pathogens where vaccines do not currently exist, such as liver fluke, sleeping sickness or Rift Valley fever, or do not confer sufficient protection such as foot-and-mouth disease or brucellosis. The recent successful development of an irradiated vaccine for malaria in humans has demonstrated the feasibility of this technique and indicated that technical problems can be overcome using up-to-date knowledge.

Field application is critical for success of new diagnostic tools

The success of novel technologies depends on having a system in place for sustainable, quality-assured delivery when transferred to and used in the field. The priority to develop rapid, specific and sensitive test systems that can be performed on-farm as well as in the laboratory was met with success modifying an isothermic molecular procedure. The Joint FAO/IAEA Division adapted this technology in order to:

- simplify the processes,
- create heat stable reagent sets,
- adapt a mobile reading device for field use, and
- reduce the costs incurred to allow for wide-scale use in developing countries.

The Division also carries out strategic and applied R&D to develop and validate immunoassays and molecular techniques at its Training and Reference Centre in Seibersdorf, Austria, in partnership with World Health Organization (WHO) and the World Organisation for Animal Health (OIE). IAEA and FAO Technical Cooperation (TC) projects ensure that these techniques are appropriately used and integrated within national, regional and global programmes for the control or eradication of major livestock diseases and zoonotic infections. These diagnostics are being used in connection with the global health programmes of WHO, OIE, the research centres of the Consultative Group on International Agricultural Research (CGIAR) and other FAO divisions.

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Adding a nuclear component

In efforts to mitigate or adapt to climate change

THE WORLD IS FACING serious food insecurity due to the adverse effects of climatic changes on soil health, and crop and livestock productivity. Nearly one billion of the world's 6.5 billion people face hunger and are food insecure. Intense competition over land and water resources for food, feed, fibre and biofuel production will be one of the major consequences of global population increase – projected to reach 9.3 billion by 2050.

As climate change and variability worsen, they will undoubtedly increase the incidences of extreme weather events such as storms, droughts and floods and, at the same time, changing temperatures may support the occurrence or recurrence of agricultural pests, diseases and their potential vectors. The increasing atmospheric concentration of greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), has been identified as the largest contributor to global warming.

All of these GHGs have been associated with the expansion of agricultural activities, such as deforestation, intensive cropping, paddy rice cultivation and livestock farming. This indicates the importance of determining the most efficient way to increase production while reducing GHG emissions. This challenge of alleviating food insecurity in a sustainable manner can only be met with integrated agricultural systems such as mixed cropping-livestock systems that include forage crops, trees or pastures, or conservation agriculture that combines reduced tillage, retention of crop residues and contrasting crop rotations.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Nuclear technology quantifies and guides efforts to combat climate change

The Joint FAO/IAEA Division is at the forefront of efforts to develop and validate sensitive and specific nuclear and nuclear-related techniques that are simple to use and provide efficient and cost-effective ways to enhance

Improving soil resilience against degradation and erosion

In China, a World Bank project in the Baota district of Yan'an has embraced information gained through radionuclide measurements to identify effective soil management practices for reducing soil erosion and enhancing soil resilience. Based on the findings that terracing, contour cultivation and no-tillage can reduce soil erosion rates by 16–80 percent, the project promoted use of cash forests, fruit tree crops and the planting of shrubs and grass. As a result, annual topsoil erosion was reduced 77 percent within six years. In addition, forest area was increased by 88 percent through reforestation, and the construction of 10 key check dams and 50 silt dams over the same period increased net farmer income from 446 to 1 754 yuan and increased grain production by 64 percent per capita.

Mutation induction increases yields in the dry and saline Andes

In Peru, mutation techniques have increased yields of existing barley varieties by up to 150 percent. Planted in zones from 3 000 to 5 000 meters above sea level, where adverse climatic conditions do not allow other crops to grow, barley is the main food security component for the 3 million people who live from subsistence agriculture in the Peruvian Andes. For example, impact analyses of mutant cultivars in the dry highlands with saline soils found mean yields had increased from 50–120 percent over the conventional varieties, which meant that farmers who were using the mutant varieties were able to increase their incomes by US$448 to US$586 per hectare.

or advance the development of integrated agricultural systems. The following identifies three main areas where the Division has taken the lead in developing and disseminating appropriate supportive technologies.

Soil management. Nuclear applications in soil, water and crop nutrition management can enhance crop adaptation and flexibility in areas that face the highest threats from changing climates. The nuclear techniques that improve soil management and thus contribute to mitigating impacts of climate change are based on the use of radionuclides or stable isotopes of carbon and nitrogen. For example, erosion and sedimentation can be assessed by monitoring radionuclides, which are widely distributed in the landscape and absorbed by soil particles. Carbon isotopes (^{13}C) can help distinguish the sources of eroded soil and place soil conservation strategies where most needed. Their reduced labour requirement gives them a strong advantage over conventional methods, such as erosion plots and pins. Nitrogen is one of the cornerstones of plant life. Nitrogen isotopes (^{15}N) can help determine the most efficient way to apply nutrients through fertilisers, crop residues and animal manures, in order to avoid the production of GHGs such as nitrous oxide. ^{15}N can also be used to quantify biological nitrogen fixation processes (BNF), through which nitrogen is absorbed from the air by plants and then left in the soil for the next crop.

Plant breeding. Modern nuclear breeding technology packages combine mutation induction and modern efficiency-enhancing biotechnologies, providing a means of following mutation events without being influenced by environmental fluctuations in the field, as is the case with standard phenotypic evaluations of plant traits. In addition, it is possible to identify mutation events in genes thought to be responsible for important crop traits such as drought tolerance or disease resistance, thanks to protocols combining mutation discovery technologies with the latest information on genome sequencing, such as Targeting Induced Local Lesions in Genomes (TILLING) for the identification of putative mutants, *in vitro* mutant selection for biotic and abiotic stresses, and micro-propagation of vegetatively propagated crops such as cassava, banana and yam.

Livestock support. Nuclear and nuclear-related immunoassays and molecular techniques support the joint efforts of veterinary authorities, extension services and farmers to control and eradicate diseases that impair productivity and trade in livestock and their products. These sensitive, specific and rapid techniques offer significant advantages over conventional methods, including the possibility of on-site use. Analytical tools such as ELISA, PCR, real time PCR and sequencing use isotopes to label protein and nucleic acid molecules and can be used for detection, monitoring, and characterization of harmful pathogens.

Methane production in ruminants is negatively correlated with energy utilization and can range from 2 to 12 percent of the gross energy intake. Radioisotopes, stable isotopes and 16S rDNA-based techniques can be used to evaluate and monitor the nutritive value of animal feeds and to enumerate and study rumen microbial diversity. Reducing enteric methanogenesis is beneficial from the standpoint of increasing energy efficiency of the animal and from an environmental perspective.

Reproductive performance and artificial insemination can be improved by monitoring various hormones, e.g. progesterone, LH, testosterone, oestradiol, T2, T3, leptines, and FSH. Also, the use of ^{32}P, ^{35}S allows the characterization and selection of desirable breeding traits.

Manipulating livestock diets to inhibit methane production

A recent Joint FAO/IAEA Division Coordinated Research Project screened more than 200 plants and plant extracts of browse, multi-purpose trees, medicinal plants and spices from Asia, Africa and Latin America. The study found that several plants and plant extracts inhibited methane production, and a large number of plants inhibited rumen ciliate protozoa. Methane production was reduced *in vitro* by between 10–100 percent and *in vivo* by 11–35 percent. These techniques which contribute to reducing the impact of ruminants on the environment, are currently being transferred to Member States through Technical Cooperation Projects.

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Nuclear Techniques in Food and Agriculture

Optimizing local resources
Nuclear techniques enhance breeding and use

WITH TODAY'S WORLD facing an ever increasing population and a host of adverse environmental trends that are likely to accelerate in the future, it becomes evident that there is a critical need to support biodiversity in order to the increase the options for breeders while also maintaining the beneficial genetic traits. It is also important to ensure that, in these efforts to improve agriculture, communities retain the benefits of their locally adapted and traditionally grown crops and animals.

For five decades, the Joint FAO/IAEA Division has worked to enhance and promote the use of nuclear techniques in responding to the challenges presented by food insecurity and has provided assistance on crop and livestock improvement to Member States. Recognizing that the world desperately needs more and better quality food products, the Division has partnered with other international organizations, national governments and non-governmental organizations (NGOs) in areas aimed at supporting sustainable and innovative agriculture, in addition to improving the nutritional value of crops and livestock.

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Crops: Mutation induction for crop improvement

Through the use of mutation induction, the rate of spontaneous mutants that come up in nature in millions of years can now be achieved in less than 10 years. Artificial mutation induction consists of using X rays, gamma rays and fast neutron irradiation to increase the frequency of mutations. Packaging this procedure with adequate efficiency-enhancing biotechnologies, such as *in vitro* culture and molecular techniques can aid in the selection of the most beneficial mutants. Harnessing these unique changes can lead to varieties that are higher yielding and better adapted and may be released as commercial varieties with added value.

Application of nuclear technologies can speed up the plant breeding process in producing the desired traits, while preserving most of the genetic background of the adapted or existing commercial varieties or preferred local landraces. As more and more mutant crop varieties are released to farmers, they make great contributions to local, national and regional food security.

Mutation induction also has proven useful in breaking linkages between adverse and favourable genes – linkages that could not be separated by conventional cross breeding. It also allows improvement of vegetatively propagated and/or sterile crops, where no mating is possible. Mutation induction has been part of the crop breeding toolkit since the late 1920s, meaning it is well tested and has proven to be a robust, cost-effective and ubiquitously applicable technology. It also has proven non-hazardous and, thus, is unregulated. This makes the technology eminently adaptable to low infrastructure laboratory environments and thus transferrable to any developing country.

Livestock: Mapping genes to improve milk and meat production

After 6 years of research by more than 300 researchers from 25 countries and US$53 million in funding, the cow genome has been defined. The Bovine Haplotype Map, as it is called, characterizes genetic diversity among breeds. Having this map allows cattle breeders to select for features they want in their cows – in particular, high quality milk. Until now, guaranteeing quality milk required inseminating cows, then waiting for the female offspring to grow and produce calves and the milk to feed them, at a cost of US$25 000 to US$50 000 per bull. Most genetic improvements in cattle come through males, because each male can produce tens of thousands of females. Already, cattle breeders are eagerly mapping single nucleotide-polymorphisms in most of their bulls, with an eye toward identifying which single nucleotide-polymorphisms are linked with good milk and other desirable qualities.

Conserving genetic diversity. Traditionally, because of the pressure for higher animal output and the trend to promote the "advantages" of a small number of highly specialized breeds from the developed world, farmers in developing countries have been replacing or cross-breeding local breeds with exotic animals. Although the genetic improvement has been quite successful in many instances, practicing selective inbreeding and use of exotic lines and breeds while neglecting or making blanket upgrades of indigenous animals has eroded genetic diversity. Indigenous animals are also underutilized in conventional breeding programmes, due to misconceptions about their value and failure to identify breeds or animals carrying advantageous traits.

Improving local feeds. The Joint Division is involved in efforts to improve the efficiency of using locally available feed resources through development, adaptation and transfer of economically viable and "simple-to-use" feeding strategies for sustainable livestock production. Examples of nuclear technologies implemented include: using ^{13}C, ^{14}C, ^{15}N, ^{125}I, ^{51}Cr, ^{3}H, ^{32}P, ^{35}S as tracers to evaluate nutritive value, passage rate and voluntary feed intake, and using doubly-labelled water (^{18}O and ^{2}H labelled) and deuterium oxide (D_2O) dilution for measurement of energy expenditure and body composition.


N. Odongo

Joint FAO/IAEA Division achieves wide success

The Joint Division is directly involved in applied research, which brings together the needs of the world's farmers with the capacity of the world's scientists. More than 3 000 officially released crop varieties of 170 different species have been improved for agronomic traits, thanks to the efficiency of mutation induction. These traits include increased yield, improved quality, resistance to disease or harsh conditions, more appropriate plant architecture and higher nutritious value.

- In Kenya, Bangladesh and Cuba, development of drought tolerant wheat, rice and tomato, respectively has significantly improved the livelihoods of farmers. A new mutant variety of the ancient Andes grain Kiwicha (*Amaranthus caudatus*) – a staple of the Incas – has been widely accepted by consumers because of its improved yield and seed quality (yellowish-white colour and larger grain). Cultivated under good agronomic practice with little or no chemicals used for weed, pest or disease management interventions, it is certified organic which means higher value and increased income for farmers. The application of mutation induction to the Kiwicha has had a socio-economic impact on thousands of native Andean subsistence farmers that can be measured by the increase of exports – from 20 metric tonnes in 2002 to 200 metric tonnes in 2009. This shows the remarkable impact of mutation induction in improving livelihoods of populations living in remote harsh environments adding to the efforts to attain the UN Millennium Development Goals.
- One salt-tolerant mutant rice variety in the Mekong Delta of Vietnam has meant US$300 million in additional income to the farmers, and another mutant rice variety with a shortened growing period allows three harvests per year, where only two were possible before.
- Bangladesh has taken advantage of support from the Joint Division to develop a self-sustaining Community-based Dairy Veterinary Service. The service measures progesterone by radioimmunoassay (RIA) in milk samples collected at specific times in relation to artificial insemination, and makes use of the Artificial Insemination Database Application to calculate reproductive indices and identify factors which affect them. This has enabled them to created a self-financing foundation which, in collaboration with farmers association and the local dairy processor, is running the programme without financial support from the university or the government.

For further information, please visit:
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