Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

IN ACTION
Nuclear applications in agriculture
On-the-ground success

Part IV

The Joint FAO/IAEA Division delivers dedicated solutions that assist member countries in their endeavours to achieve the United Nations' 2030 Agenda for Sustainable Development – transforming our world.

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- To increase farmer income through improved crop productivity by mutation breeding
- To increase productivity and reduce livestock loss from animal diseases through effective vaccination and control techniques
- To enhance access to markets through effective food authenticity systems

End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

- To improve crop yield, nutritional value and genetic diversity through climate-smart plant mutation breeding
- To reduce losses in crops, livestock and human health through area-wide integrated management of major insect pests using sterile insect techniques
- To facilitate adherence to food safety standards through effective and validated monitoring techniques for food and agricultural products
- To improve nutrition of animal products through breeding and enhanced feed resources

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- To increase agricultural water use efficiency through nuclear techniques for water saving agriculture
- To improve water quality through optimization of crop nutrient use efficiency and reduction of suspended sediment
- To optimize the use of scarce water resources through drought-tolerant mutant varieties
- To protect water-related ecosystems through integrated water management practices

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- To reduce food losses along production and supply chains through application of food irradiation
- To optimize the use of agrochemicals through effective monitoring and analytical techniques
- To enhance the nutrient-use efficiency of crops through mutation breeding

Take urgent action to combat climate change and its impacts

- To measure and evaluate the impact of climate change through monitoring and minimizing greenhouse gas emission
- To improve climate resilience of agricultural crops through plant mutation breeding
- To strengthen early diagnosis and control of transboundary animal and zoonotic diseases under climate change through application of nuclear and nuclear-related techniques
- To facilitate climate-smart agricultural practice through integrated application of nuclear techniques

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

- To enhance the use of water-scarce ecosystems through optimisation of soil, crop, water and nutrient management practices
- To increase the biodiversity and facilitate sustainable use of plant genetic resources through plant mutation induction and application
- To facilitate the protection, remediation and restoration of terrestrial agroecosystems in line with obligations under international agreements through nuclear and radiological emergency preparedness and response

Strengthen the means of implementation and revitalize the global partnership for sustainable development

- To enhance South-South, North-South and triangular regional and international cooperation, knowledge sharing and access to science, technology and innovation through the FAO/IAEA partnership
- To advance food security and sustainable agricultural development through coordinated research projects (CRPs) and technical cooperation projects (TCPs)
- To enhance knowledge sharing, experience and skills through networking across national agricultural research and extension systems

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ARGENTINA

Argentine farmer folklore of parasite-resistant sheep now backed by science

At one point, farmers' belief that some of their sheep were naturally resistant to gastrointestinal parasites was put under the heading of "farmer folklore". However, as parasites began to develop resistance to drugs used to kill them, and the world's farmers dealt with losses due to parasites estimated in billions of dollars, researchers began seeking scientific evidence that would form a basis of breeding for natural resistance. As it turned out, farmers were right. Not only are some sheep naturally resistant to parasites, there are relatively easy ways to tell which ones are, such as checking the conjunctiva colour in their eyes, but also more advanced scientific ways, which identify the genetic markers of resistance. In Argentina, where mutton and wool are enormous contributors to the agriculture sector, the Joint FAO/IAEA Division works with the National Institute for Agricultural Technology (INTA), which maintains a large flock of sheep to record results of breeding. Incorporating data on natural resistance into breeding programmes has meant millions of dollars in extra income for Argentina's sheep farmers.

Wool and mutton production is an important contributor to Argentina's agricultural sector, bringing an annual export income of more than USD 210 million, which is second only to the country's beef cattle production. As with other countries worldwide, Argentina's sheep farmers are constantly at battle with gastrointestinal parasites that attack their flocks – a scourge that has an ongoing impact on quality and quantity of their production.

Research on this topic, spearheaded by the Joint FAO/IAEA Division, has concentrated on identifying animals that have natural resistance to parasites and used that information to help farmers improve their breeding programmes. Breeding for natural resistance allows farmers to reduce or even avoid the cost of drugs used to treat parasite infections, which is especially important in the developing world, where farmers often cannot afford the drugs in the first place. In addition, although veterinary pharmaceutical companies constantly release new drugs to treat parasite infections, within a few years, the parasites develop resistance. This problem is multiplied because farmers who cannot afford to buy required amounts of drugs may reduce the dosage or use it less often than recommended, both of which would speed up

the process of parasites developing drug resistance. The situation is further compounded by potential contamination of food with anti-parasite drug residues.

Breeding for parasite resistance saves farmers millions of dollars

Argentina's National Institute for Agricultural Technology (INTA) maintains a flock of 2 000 sheep on its campus in the Patagonia area where, for many years, researchers have recorded animals' weight and wellness: if they are resistant to parasites, they should have a normal level of red blood cells and steady weight gain; if susceptible, they should lose weight and become anaemic, which is one symptom farmers could identify easily, since healthy animals have dark pink conjunctiva but anaemic ones have pale conjunctiva. It is also possible to check for parasite infections with a blood test or by counting parasite eggs in the animals' faeces, which reflects the number of mature parasites living in the gastrointestinal tract of the animal. The more resistant the animal is, the lower the number of mature parasites, and thus fewer eggs are released in the faeces.

But parasite level is not the only parameter for breeding. Farmers also want to improve their sheeps' wool quality, meat and milk production, growth rate, reproductive efficiency and survival rates. As the Joint Division and its counterpart institutes have increased their knowledge base, they have added a genetic element into decision-making for breeding. This is where the process moves from the field into a laboratory where it is possible to study an animal's DNA. The Joint Division has introduced a nuclear-derived molecular technique to identify specific

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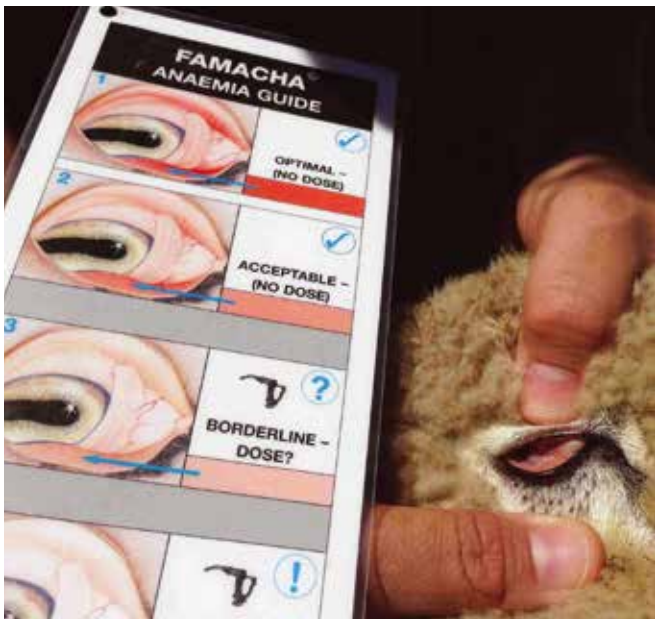

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DNA markers of resistant animals across two or three generations, which can then be incorporated into a genetic evaluation that enables breeders and farmers to make the best possible breeding decisions.

Funded by the IAEA's technical cooperation programme, the Joint Division provided INTA with guidelines and protocols for recording quality data. It also trained a local scientist in the genomic techniques and analyses of bioinformatics data, and field staff in proper ways to collect quality data and DNA samples. The breeding programmes need the data and samples to ensure that the rams chosen for breeding are parasite resistant. Once they have identified the more resistant animals, they can either sell the rams or use artificial insemination to disseminate the resistant traits among the sheep population.

Breeding for parasite resistance means helping farmers prevent loss of animals and improve wool production. Wool loss for animals infected with parasites is estimated at between 15 and 20 percent per year – equivalent to 1 kg of fleece per animal with a value of about USD 1. So if the wool is not lost due to parasites, it adds up to Argentine farmers having an extra USD 30 million each year in income. The farmers also will save about USD 70 per ewe and USD 400 per sire ram, due to longer life expectancy and increased wool and meat production.

With its success in breeding for parasite resistance, INTA and the Joint Division are sharing what they know. They are providing expert services and training professionals in other Latin American and Caribbean countries that have similar problems and, hopefully, will find similar solutions.

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BANGLADESH

Artificial insemination of cattle supports boost in milk and meat production in Bangladesh

Modern animal breeding technologies, a network of artificial insemination services, a flourishing feed industry and functional delivery of veterinary services have had an extremely positive impact on milk and meat production in Bangladesh, especially for its crossbred cattle. In the past decade, the country has seen a 4-fold increase in milk production and 7-fold increase in meat production. The Bangladesh Agricultural University (BAU) in Mymensingh and the Bangladesh Department of Livestock Services (DLS) played important roles in this development, with technical support offered by the Joint FAO/IAEA Division. The work with BAU focused on increasing the success rates of artificial insemination, working through a farmers' organization with 800 members. But the project's goal of improving both the genetics and conception rates of the cows was so well received that it spread across the country. Nearly 6 million cows were artificially inseminated in the country during 2017 alone.

Bangladesh has more than 25 million cattle, and 9 million of them – 35 percent – are crossbred. This means they are a mixture of everything and, in most cases, the mixing was done on individual farms without much thought to the science and techniques of genetic evaluation in the nationwide breeding programme. The Joint Division has been working with the Bangladesh Agricultural University (BAU) since 2000, with a goal of helping dairy farmers make better breeding decisions, especially through improving outcomes of artificial inseminations for their animals.

As a start, the Joint Division, BAU and Bangladesh Department of Livestock Services (DLS) characterized the genetics of crossbred animals, identifying superior animals whose parents may not be known but their genetics indicate they have traits that can be passed to offspring to improve herd productivity. Based on this genetic information, farmers started using artificial insemination from the selected superior sires to improve their herds' production. This was an important first step. But to make this successful, farmers must know when their cows are ready to be bred.

Training empowers smallholders to make a difference in cattle industry

In Bangladesh there is no free-range grazing. Animals stay tethered near the homestead, and fodder is brought to them as "cut-and-carry". If the cows were free ranging, it would be easier to spot those in heat by the way they

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act in the field with other cattle. But when they are tethered, farmers must learn to identify specific actions or behaviours that mean they are in heat – so that the insemination can be done at the right time.

Usually this kind of project is adopted by farmers in one farming community, while neighbouring farmers will try something else. But this project has been adopted by the entire country and it has paid off with new generations of offspring that have much higher production of milk and meat. As the number of farmers grew, so did the work of those who had to administer it.

The BAU runs a continuing education programme on reproductive health management, which has trained 95 practicing veterinarians, over 1 000 insemination technicians and 625 community veterinary health workers with funding provided by several development organizations. It has also set up mobile clinics so technicians and veterinarians can go to the villages and give advice on feed but also inspect animals and suggest treatment if necessary. At the same time, it created the Community-Based Dairy Veterinary Foundation with a membership of 800 smallholder farmers, who, in turn, have trained 2 900 smallholder dairy farmers and 50 field workers who can pass on information about udder hygiene and neonatal care.

For smallholder farmers who only have a few animals, the best-case scenario is for the cows to have offspring every 12 months. Thus, the project incorporates radioimmunoassay (RIA) of reproductive hormones– a monitoring test that uses the radioisotope iodine-125 to determine what phase of her oestrous cycle the cow is in.

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If it finds she is not pregnant, then samples collected at insemination can determine why – if it was a problem of the animal, if the farmer was not correct in detecting heat, or sometimes the inseminator did a bad job. It also can determine how quickly the animal can be re-inseminated.

As this project has grown, so had its package of methods, techniques and advice that can be shared through clinics. Today, farmers are getting more pregnant females because the genetic quality and fertility of bulls used to collect semen is better – the offspring are healthier and grow faster, with females producing more milk and cattle in general producing more meat. As the package of services has expanded and stories of success circulated, villagers across the country have formed farmer associations and asked for support from the mobile clinics and trained insemination technicians. With the income from the improved milk and meat production, they can buy feeds, medicines, pay the inseminators and deliver milk to cooperatives at a better price.

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THE CONGO

Fast response to HPAI outbreak avoids economic losses in the Congo

At the end of May 2017, the Congo (DRC) was faced with what appeared to be its first-ever outbreak of highly pathogenic avian influenza (HPAI). Rapid confirmation was critical. Animal and public health officials needed to know if it really was the avian influenza virus, and, if so, which strain of the virus was present. The Central Veterinary Laboratory in Kinshasa, the capital city, was prepared with sampling and testing protocols to deal with the emergency. The Joint FAO/IAEA Division had previously provided the lab with diagnostic equipment and training for staff both in the lab and in the field. Thus, when samples from the outbreak area were brought for analysis, the lab was prepared, and it quickly determined that, yes, it was avian flu. Although it would take more time to find out exactly what strain was present, the veterinary service activated a precautionary response programme. While previous outbreaks in Africa had meant the loss of millions of birds, the fast reaction in the Congo meant the outbreak was contained with minimal poultry losses and no human casualties.

When DRC's Central Veterinary Laboratory (CVL) in Kinshasa received notice of significant unexplained duck mortality in the Ituri area, which borders Uganda, the logistics could not have been worse. There was suspicion that the mortality was due to avian influenza but samples had to be gathered and taken on a 1 000 km journey across bad roads to the lab for testing. As it happened, CVL was well prepared to deal with this potential emergency.

Many laboratories in Africa and Asia have insufficient infrastructure and capacity to perform diagnosis on major transboundary animal and zoonotic diseases and have to send their samples to external reference laboratories for diagnosis. This creates a delay in diagnosis and implementation of control measures that gives the disease time to spread.

However, thanks to staff training and equipment that had been received from the Joint FAO/IAEA Division, CVL, as part of the VETLAB Network of 44 African and 19 Asian participating countries, was able to set up a rapid diagnosis response. It had trained field staff in the Ituri area who knew how to collect and transport the samples correctly, and the lab itself had the appropriate equipment and reagents on hand as well as the qualified staff to conduct the necessary polymerase chain reaction (PCR) diagnostic tests to determine what virus they were dealing with.

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Previously, laboratory tests took weeks, but now, with the acquired skills and VETLAB support, the detection and diagnosis at CVL took only a few hours. In all, CVL was able to send confirmation back to the affected field services that, indeed, it was avian influenza. It then was necessary to determine exactly which strain of the virus was present – high or low pathogenic – a step that requires genetic sequencing.

Joint Division offers access to gene sequencing

Using genetic sequencing procedures in Member State labs requires big investments in specific equipment, consumables and training for relatively low sample loads. In order to offer Member State's labs access to such services through an external provider, the Joint Division provides counterpart laboratories with instructions on how to prepare the samples for submission, evaluate their quality, ship them using rapid post services and receive the results within 24 hours, as well as protocols for interpretation of the obtained results and sharing the data on public genomic databases. The sequencing service is funded by the Joint Division and is part of the VETLAB Network activities.

So, even as CVL sent its samples to the Joint Division's genetic sequencing provider, the veterinary service at the CVL and in the affected region had already moved ahead. Taking precautionary steps, it enacted its response protocol, which called for alerting regional and international authorities that the disease was present, implementing trade restrictions and culling poultry in the infected villages and the farms.

When the genetic test results came back, they confirmed CVL's initial diagnosis and also determined that it was indeed the highly pathogenic strain. Because of the quick response of the laboratory and the veterinary service, the infection was contained in one single administrative district and the last case was observed in July – just two months after it began. In addition to containing losses, the country greatly minimized an outbreak that could have had an enormous economic impact on the country and the region, especially considering that more than 8 million birds had been lost due to HPAI infection in Africa in the previous four years.

If this had happened just a few years earlier, the veterinary service would have had to send the initial sample to Europe or America for testing – a very expensive and time-consuming process. Now, with its own laboratory able to handle the initial diagnoses, and with rapid access provided to the external genetic sequencing services, DRC saved money – but above all, it saved time, which is so important when trying to stave off the spread of an epidemic.

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ZAMBIA

Accreditation recognises competence of Zambian veterinary laboratory for diagnosing and reporting animal and zoonotic diseases

In Zambia, livestock provides subsistence income to more than 80 percent of the country's smallholders and contributes more than 40 percent to the agricultural share of GDP. In November 2017, when Zambia's Central Veterinary Research Institute (CVRI) received a word that it had achieved ISO 17025 accreditation, the news was well received by the veterinary authority, the farmers and the business community in the country – they all had waited a long time for a competent laboratory to certify that their animals and animal products are free from diseases of trade concerns. The accreditation also took CVRI to a higher level in its support to the livestock disease monitoring and surveillance programmes. This was largely a result of efforts made by the Government of Zambia, working with the IAEA in partnership with FAO, especially the Joint FAO/IAEA Division and its VETLAB network, to modernize its equipment and increase staff capacity to diagnose animal diseases quickly and accurately. This is particularly important in countries such as Zambia, where rapid diagnosis enables containment of deadly disease outbreaks which, if allowed to spread, will have a damaging impact on the livestock industry, public health (in case of zoonotic diseases), community livelihoods and trade.

Newcastle disease, foot and mouth disease, African swine fever, East Coast fever, lumpy skin disease – the list of economically important, contagious animal diseases that are endemic to Zambia is long. But, thanks to the increased monitoring and surveillance capacity of Zambia's Central Veterinary Research Institute (CVRI), the country is now prepared to contain or even prevent disease, or contain outbreaks. The institute's laboratory staff works persistently to remain ahead of any potential problems, regularly monitoring safety of livestock products. It also conducts epidemiological studies of major diseases, against which the government has been developing control programmes and stockpile specific vaccines, to be prepared in case they are needed.

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National animal disease control plans call for providing early and rapid diagnosis but also the competence to certify that animals and animal products are free from diseases, especially for trade. Every disease has a different epidemiology and knowing exactly its cause is the first and most important step in activating effective control programmes. Through constant training, capacity building and support from the Joint FAO/IAEA Division's VETLAB Network, CVRI's accreditation under the international ISO 17025 acknowledges that it has the technical competence needed to diagnose a wide range of animal diseases. This has resulted in the reducing the time for a diseases diagnosis and its subsequent confirmation from several weeks to just a few days.

Before it had this capacity, Zambia had to send samples outside of the country for confirmation of the pathogens, which was expensive and time consuming because it required compliance to international safety procedures related to shipping potentially infected samples. Now that the CVRI is accredited, the veterinary authority will know the cause of the disease immediately and will only occasionally send samples abroad when more advanced technologies are required for further confirmation of its diagnosis. When there is a risk of an outbreak from an endemic or emerging disease, a delay of even one day can greatly increase the spread and, in turn, its impact on public health and the economy of the country.

VetLab Network remains the key in achieving the accreditation

The CVRI laboratory is one of the 44 African and 19 Asian laboratories that make up the Joint Division's VETLAB network. The CVRI's participation in the VETLAB network and its long collaboration and partnership with the Joint Division resulted in training of professionals to much higher-level skills, upgrading its laboratories with modern equipment and testing, validating and standardizing its laboratory protocols and challenging and finetuning its standard operating procedures (SOPs). All these have helped CVRI meets the requirements of the ISO 17025 standard. The standard defines a laboratory as an organized legal entity with appropriate facilities and working environment that ensure the use of calibrated and tested equipment, validated protocols and SOPs, and keeping proper records for easy retrieval, analysis and reporting. ISO 17025 standardising authority confirms all these though annual audits.

CRVI received its ISO accreditation from the Southern Africa Development Community Accreditation Services (SADCAS). Looking ahead, the CRVI will receive regular support from the Joint Division to ensure that it continues to implement the most updated, internationally recognized procedures in disease diagnosis, and hence maintains its ISO standing.

This kind of advancement is increasingly seen across Africa and Asia. Already in the Southern African development community (SADC) region, Zimbabwe and Botswana have also received ISO accreditation, and Lesotho, Swaziland and Angola are striving to achieve ISO compliance.

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BENIN

Benin food safety lab opens door for beekeepers to export honey to EU market

When it comes to production and export of honey from West Africa, farmers have been known to joke that "bees secrete honey – bees secrete money", because in terms of return, honey is a very lucrative export product. In Benin, honey is produced mainly in the northeast part of the country but, due to stringent food safety requirements for exporting countries, farmers did not have authorization to export their produce to lucrative markets such as the European Union (EU). That changed in February of 2018, when the European Commission informed Benin that its honey monitoring plan had been approved and the country could export its honey to the EU. In part, this approval can be credited to the standards met by Benin's Central Laboratory of Food Safety Control (LCSSA) which, with the support of the Joint FAO/IAEA Division, has received accreditation by a Belgian accreditation body and is now trusted to monitor the country's agricultural production, including honey and pineapples.

Beekeepers in Benin produce about 600 tonnes of honey and 40 tonnes of beeswax each year. Even though honey is an extremely lucrative agricultural export, all of this production has been dedicated to local and regional production because the country has not had approval to export to lucrative markets such as the EU. That said, a door has now been opened – and export can begin – due, in part, to the country's improved capacity to address international food safety and trade standards.

For honey, this meant establishing a monitoring plan to ensure that the honey coming from the hives of northeast Benin is safe, including testing for residues of veterinary drugs, pesticides or toxic metals that the bees might have picked up when out doing their pollinating chores.

In 2015, Benin exporters had been having trouble with exports of agricultural produce, especially pineapple, which had been found to contain unacceptable levels of a pesticide residue. Pineapple shipments were being rejected by importing countries, which led the country to take the pro-active step of banning all exports of pineapple until it could improve its food safety surveillance system. This decision had a big impact on the farming sector – both its income and employment.

Benin takes pro-active step to build laboratory capacity

Taking a step back and improving its surveillance system meant that Benin needed to improve its in-country laboratory capacity to assess and monitor agricultural production. Without that capacity, the

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country would have had to outsource its food safety testing, which is both expensive and time consuming. The ultimate goal was to achieve accreditation for Benin's Central Laboratory of Food Safety Control (LCSSA).

Through a technical cooperation programme, LCSSA received support from the Joint FAO/IAEA Division, including equipment and reagents needed for conducting the required analyses. LCSSA staff members were also trained in use of radioreceptor assays and stable isotope techniques required for conducting the necessary assays and for testing food samples for contaminants and pesticide residues. Building the laboratory's competence and reliability also included training staff members to operate the equipment correctly and interpret the test results.

In 2017, Benin got the answer it was hoping for. The Belgian accreditation body, after a very detailed evaluation of the laboratory capabilities, granted LCSSA accreditation with regard to its competence and reliability. This meant LCSSA was recognized for its ability to monitor and analyse agricultural produce, including analysing samples from farms around the country and airports. It also could provide timely feedback to enhance good agricultural practices. By testing farm products prior to export, there would be no fear of importers rejecting shipments.

Having attained competence, Benin soon lifted its self-imposed ban on pineapple exports and its farmers now export their produce to the EU. And as for honey, when Benin presented the EU with its national honey monitoring plan, all moved smoothly. Importing countries knew that the honey from Benin would be analysed and tested by an accredited laboratory, and farmers knew that they would be given all information needed to ensure that their production met international food safety standards. And EU consumers would be able to purchase Benin's unique honey – with the taste of West Africa.

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PANAMA

Panama laboratory protects consumers and the environment, and increases market prices

Each year, the Pesticide Residue Analysis Laboratory of Panama's Ministry of Agriculture (MIDA-SV) analyses some 3 000 samples of agricultural crops for contaminants plus another 200 agrochemicals that have been approved for farmers to use in their fields. With these analyses, farmers have confidence in the chemicals they apply in their fields, and consumers and trade markets have confidence that produce they are buying is safe. Since it was created in 2006, the MIDA-SV laboratory has been working with the Joint FAO/IAEA Division, receiving instruments and equipment, and building staff capacity to test for pesticide residues in order to ensure that agrochemicals have been applied properly. These findings are not only important for consumer safety, they have a big impact at the market. Producers who have their crops tested by MIDA can count on receiving a 20 percent higher price in the market than those who do not go for testing.

Use of the pesticide chlorpyrifos has been restricted in Panama since 2011, but the Ministry of Agriculture's Pesticide Residue Analysis Laboratory (MIDA-SV) continues to find traces of it in the country's fresh water and rivers. Described as a challenging situation, this indicates that the massive amounts of the chemical applied incorrectly in the field have gone into water bodies and that a lot more remains in nature. With this knowledge, MIDA now works with farmers to make sure they understand the chemical's correct application and, at the same time, continues testing for further signs of health or environmental hazards from chlorpyrifos. This is just one situation in the agricultural sector of Panama that highlights the extremely important role played by its analytical community in testing both agricultural products and the environment for contaminants and potential health and safety hazards.

When the MIDA laboratory officially began operation in 2006, its analytical equipment was scarce. But with the support of the Joint FAO/IAEA Division, it has continuously upgraded and modernized its equipment and its expertise in conducting essential protocols and tests. It also has taken a proactive role by providing information to other departments at MIDA that provide farmers with manuals and guidelines as well as field training, to make sure they understand the proper steps that lead to good agricultural practices. Farmers have reacted positively to this opportunity, taking advantage

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of the training in order to show the markets that they have taken appropriate steps to ensure their production is safe for consumers and the environment.

Contaminant analysis protects internal and export markets

MIDA-SV provides the agricultural sector with two types of analysis – contaminant analysis tests for residue of pesticide application in the field, serving both the internal and export market, and post-registration formulation control analysis, which ensures that government-approved, registered agrochemicals comply with the information on their labels. With quality control on the formulation, MIDA-SV is able to ensure that farmers understand the uses of the chemicals they apply and how to apply them safely.

This is all part of Panama's national monitoring programme, designed with the support of the Joint Division. In addition to the contaminant and formulation analyses, MIDA-SV also provides analytical services and conducts testing for the Ministry of Health, which takes samples from local markets, and for the Autoridad Panameña de Seguridad de Alimentos, the authority responsible for food import control, which takes samples from import markets.

In its support of MIDA-SV, the Joint Division provided instruments and equipment, introduced cutting-edge technologies and methodologies, and organized capacity-building training for the staff. With this support, MIDA-SV has become a recognized national reference laboratory for pesticide residue analyses. It also is now able to participate in larger research projects, with staff members demonstrating they can apply what they have learned and can continue to increase their competencies.

Parallel to this, MIDA-SV adopted a technology to conduct rapid screening in the field for "positive samples". This reduces the number of samples that the analytical laboratory has to test with confirmatory technology. The IAEA, through its technical cooperation programme, provided funding for the purchase of mass spectrometry instruments that helped increase the testing scope from 17 pesticides in 2008 to 156 in 2017. The Joint Division also hosted MIDA staff at its FAO/IAEA Agriculture & Biotechnology Laboratories in Seibersdorf, Austria, introducing new levels of testing as well as risk-based monitoring programmes for fresh produce control. Through the continuous support, guidance and method protocols provided by the Joint Division, MIDA-SV now provides essential services for the entire analytical community, testing for food safety and environmental analysis not only for pesticides but also for fertilizers, heavy metals and other inorganic contaminants.

MIDA-SV now maintains a series of satellite centres where local farmers can take their produce to be tested for pesticide residues. If the spectrophotometer screening detects residue, the farmers are referred to the MIDA-SV laboratory in the capital city, which can provide further testing and advice on how to avoid such problems in the future. This certainly helps farmers who grow crops for export, but MIDA-SV also has a keen focus on the internal market and internal consumers.

Building from what has been accomplished with MIDA-SV in Panama, the regional network of analytical laboratories in Latin America (www. red-ralaca.net) is now proposing a regional endeavour that will focus on internal markets and consumers.

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TANZANIA

Food poisoning cases in Tanzania rallies support for food safety measures

In June of 2016, a deadly outbreak of suspected food poisoning gained national attention in Tanzania. It was associated with the deaths of seven members of one family and by the time it ended, ten more suspected cases had led to deaths, and more than 50 people had been hospitalized in the Dodoma and Manyara regions. The nation's newspaper coverage brought it to the attention of worried consumers. The Tanzania Food and Drug Authority (TFDA) launched a campaign to identify the source of the poisoning and develop an action plan to prevent future food safety crises. After taking hundreds of food samples through its laboratory, established with support of the Joint FAO/IAEA Division, the culprit was identified as maize, which had been contaminated by aflatoxins at farm level.

The Tanzania Food and Drug Authority's (TDFA's) food safety laboratory was on the front line of the effort to stop and trace the cause of a deadly food poisoning outbreak suspected of taking the lives of 17 people and putting dozens more in the hospital. The coverage of the outbreak served an important purpose: it rallied the country, raising public, government and donor awareness of the importance of monitoring and testing food products, all along the food chain – from the farm, through processing, packaging, transporting all the way to retail outlets and export markets.

The ISO certification of TFDA's food safety laboratory, which was achieved with Joint FAO/IAEA Division support, meant that TFDA had both the equipment and the trained staff necessary to follow the outbreak back to its cause. When the outbreak occurred, the Ministry of Agriculture and Livestock and the Ministry of Health initiated an investigation and, in collaboration with the US Centers for Disease Control and Prevention (CDC), conducted tests on blood and cereal samples that identified and associated the presence of aflatoxin B1 with the outbreak. Aflatoxins are known to damage the liver. They can cause liver cancer and also suppress the body's immune system. High levels of exposure can result in liver failure and, as was suspected in Tanzania, lead to death. Current studies are also investigating if aflatoxin contamination may be associated with impairing the physical and cognitive growth of children.

The CDC corroborated work done by the TFDA, indicating that the cereal samples tested had the highest level of aflatoxins ever recorded. Yet, Tanzania is not alone. Aflatoxins are an enormous problem throughout Africa, resulting in the loss of USD 450 million worth of food goods each year. The CDC estimates that more than 4.5 billion people in the

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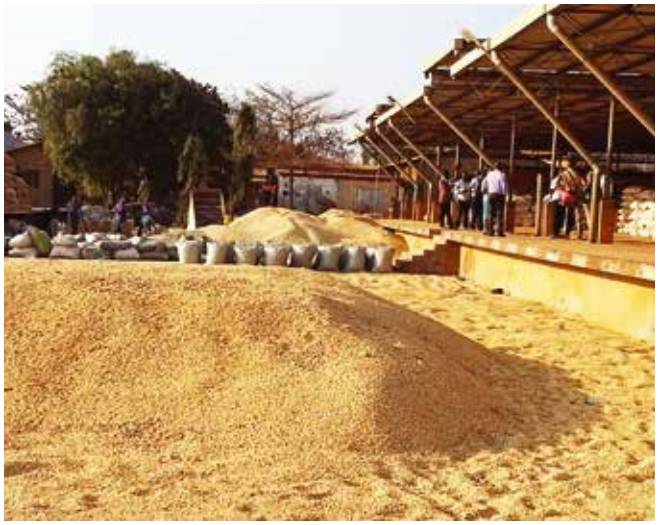
developing world are exposed to aflatoxins through the food chain. Although exposure to small amounts of the toxin may not present immediate symptoms, it still can impair health. Its presence in the food chain also presents serious obstacles to welfare, impacting agricultural production and smallholder farmers' access to markets.

Aflatoxin presence traced to poor post-harvest practices

Governments tend to be interested in food safety because of the need to meet standards set for international food trade. But this suspected aflatoxin tragedy galvanized the Tanzanian government, creating awareness of the importance of the laboratory and its staff in maintaining the safety of Tanzania's citizens. In this case, when the aflatoxin-suspected poisoning was traced back to maize, it showed the importance of ongoing and reliable monitoring and a sound, well equipped laboratory using radioreceptor assay techniques and complementary tools. With 45 percent of its cultivated land dedicated to maize, Tanzania is the largest producer of maize in East Africa. As the country's major staple food, maize also accounts for more than 70 percent of the cereal produced in the country. However, the maize market may be affected by failure to meet safety requirements due to presence of hazards such as aflatoxins.

In addition to detecting aflatoxins and associating them with the poisoning, the TFDA also determined that the maize contamination resulted from poor post-harvest preservation. Aflatoxins are produced by fungi which rely on suitable moisture levels to grow. This means that with proper drying and storage of crop produce, the production of mycotoxins may be limited or avoided.

As a result of the work done by the TFDA – using capacity built with support of the Joint Division – Tanzania's Ministry of Health and Ministry of Agriculture and Livestock have begun collaborating to educate the public on how to preserve their foods safely and limit fungal growth. Further, the TFDA has increased and improved sampling along the food chain and now also samples grain stores and markets. Efforts are also underway to document the extent of mycotoxin contamination and to develop a comprehensive and lasting solution to reduce mycotoxins in the country, which, in turn, will improve the livelihoods of the population and reduce loss of income due to the banned trade of contaminated food.



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ZAMBIA

Mycotoxin control benefits public health and economy of Zambia

Each year, countries in sub-Saharan Africa lose more than USD 450 million in trade revenue from major staples, particularly maize and groundnuts, as a result of contamination from deadly aflatoxins. Presence of aflatoxin not only keeps tainted products out of international trade, it keeps it off local market shelves. The toxin is produced by a fungus that can easily find its way into crops at any point, especially if the crops are not properly dried during the post-harvest stages. In Zambia, the National Institute for Science and Industrial Research (NISIR), with the help of the Joint FAO/IAEA Division, set up a laboratory network with particular focus on mycotoxin control, to increase food safety for both local consumers and export markets. A routine sampling found contamination in peanut butter, which proved especially important considering that peanuts are a major staple food in Zambia.

In September 2016, the Zambia Bureau of Standards, part of the country's laboratory network, seized over 11 000 containers of aflatoxin-contaminated peanut butter from various shops in the capital city, Lusaka. During the Bureau's routine market sampling, the peanut butter had been found to contain dangerously high levels of aflatoxin, which is a deadly and carcinogenic food poison that can cause serious illness and death, and has been suspected of contributing to stunting in children and retarding productivity of both people and animals. In addition to the threat to public health, taking contaminated products out of the food chain means less food for the people, hence, impacting food security.

After the alarm was sounded in the capital city, warnings were sent to the rest of the country and all suspected containers of peanut butter were pulled from the shelves. This incident had an impact well beyond the peanut butter recall, because of its effect on trade. In the past, Zambia already had problems with food shipments being rejected for export because they tested high in aflatoxins or other types of mycotoxins or food contaminants.

The Joint FAO/IAEA Division, in its support of the food sector in Zambia, has worked with several laboratories and regulatory bodies to set a national monitoring programme. In 2017, it supported the establishment of a NISIR laboratory with specific expertise in mycotoxin sampling and testing. This included providing the proper instrumentation and training laboratory staff in use of the instruments, as well as setting up a national plan for sampling. Because farming of groundnuts and maize, which is also highly susceptible to aflatoxins, occupies a wide area of the country, satellite laboratories are

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being established in the countryside to do initial sampling and testing for food contaminants. If they find a problem, they send it to the NISIR laboratory for further testing and confirmation.

Food chain sampling supports producers, consumers and traders

In addition to knowing what kind of contaminant is present, it is important to know exactly where it entered the food chain and also to be able to return to the farmer or producer with information on how to prevent that contamination in the future. This type of sampling brings the food safety service much closer to the people who need it – the producers and the consumers as well as those involved in food trade. The laboratories in the network, guided by the Joint Division, are now able to use isotopic methods to analyse and test for food contaminants, and farmers' produce can be tested in the country prior to export, so there is no fear of a shipment being rejected or sent back from an importing country.

It is not unusual for governments of developing countries to have a strong interest in protecting trade, because a good export market contributes to the national economy.

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However, in addition to working with the trade sector to ensure its production is fit for trade, the Zambian national monitoring system now also focuses on protecting local consumers. It brings together the people who set the national food safety regulations, regulators who implement them, laboratories that test the foods and, of course, the trained staff members who conduct the tests and have the know-how to follow up if the results are positive. Supported by the Joint Division, staff members receive training in neighbouring countries and also participate in on-site proficiency testing. As proficiency has increased, NISIR and its counterparts have added tests for other food contaminants, such as residues of animal drugs and other agrochemicals.

One positive outcome of the contaminated peanut butter incident was the strengthening of Zambia's national food safety monitoring programme which has had a positive impact for the people of Zambia. Peanut butter is an extremely popular food in Zambia, but this particular batch contained an invisible but deadly poison. Identifying and removing such contaminants prior to market entry helps safeguard consumers and raise awareness of the usefulness of a network of testing laboratories devoted to food safety. Today it is aflatoxins in peanut butter, tomorrow it may be another contaminant in a different food product or consignment. Capacity built in the country with support of key partners ensures that the country remains vigilant.

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THE DOMINICAN REPUBLIC

Released sterile flies free the Dominican Republic of medfly infestation

Twice a week, from October 2015 until April 2017, plant protection officials of the Dominican Republic went to the airport to meet a plane bringing a unique cargo from Guatemala. The planes were carrying boxes containing the pupae of up to 82 million sterilized male Mediterranean fruit flies (medflies). The pupae were transported to an emergence centre where they were held for few days, with sugar and corn flour fed to the emerging adults before their field release. Adult flies were chilled to immobilize them, placed in temperature controlled boxes loaded into planes and released in medfly infested areas. This scenario is a typical operation in what is known as the sterile insect technique (SIT), a technology used over many decades that controls and can eradicate pests by sterilizing males and releasing them in infested areas to mate with wild females who then produce no offspring. In the Dominican Republic, the arrival of the sterilized medfly pupae and adult release to initiate SIT was the final step in a programme to eradicate a medfly infestation that had shut down the country's horticulture trade.

The Caribbean Region had always been free of the invasive and destructive Mediterranean fruit fly –until March of 2015, when one medfly was spotted in a lone almond tree in the eastern region of the Dominican Republic. It, apparently, all started when a cruise ship docked at Punta Cana, a popular tourist destination at the island's eastern tip, carrying fruit infested with the dreaded medfly. When its presence was discovered, the Ministry of Agriculture, through its plant protection authorities, took steps to assess the size of the infestation and to contain the outbreak.

This is a pest that harms fruit and vegetable production. It also interrupts trade, because importing countries that are free of the pest often restrict horticulture imports from countries where the medfly is present. Although the Dominican Republic had taken initial action, when its efforts proved insufficient to stop the infestation, the national authorities requested support in setting up a country-wide surveillance network and an eradication campaign. Immediate support was provided by FAO and IAEA through their Joint FAO/IAEA Division and the IAEA's Technical Cooperation Department, as well as by the US Department of Agriculture (USDA) and the Guatemala-Mexico-USA Moscamed Programme. Other organizations, including Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA) and the Instituto Interamericano de Cooperación para la Agricultura (IICA) also provided valuable support.

Although the government reacted when the first medflies were found, so did the country's trading partners. Within a week of the government's alert that the medfly had been detected in the country, its

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main trading partner, the USA, had banned imports of 18 agricultural products, including avocado, tomato, bell pepper and mangoes. The ban stayed in force while the agricultural authorities, together with the collaborators, set up and implemented their eradication campaign.

Surveillance identifies 2 000 km² medfly infested area

The campaign began by setting up a surveillance network with traps around the epicentre of the fly find, extending geographically until it found the perimeter of the infestation. Although it identified an infestation of more than 2 000 km², this area was approximately 200 km from the nearest horticulture production site. The surveillance network revealed that the rest of the country was clean. So the eradication campaign targeted the infested area in the eastern part of the country.

First step was to suppress the medfly population, using ground bait sprays and bait stations placed on trees. Any host fruits where the medflies might lay eggs were collected and disposed of, and the almond trees that had hosted the first indication of medflies – the primary medfly host – were heavily pruned. SIT was used as the final step of the medfly eradication process – a clean-up operation to eliminate any populations that remained.

SIT works most efficiently if the pest population has already been suppressed, because the sterilized male flies mate

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with the remaining wild females. It would be prohibitively expensive and less effective to apply SIT when the population is high.

So, starting in October 2015 and ending in April 2017, each week up to 82 million sterilized flies were shipped to the Dominican Republic from their rearing facility in Guatemala. The campaign went so well that in January 2016, trade reopened with the USA, while the SIT eradication was still underway. However, as an illustration of the economic devastation that accompanies a medfly infestation, in the initial nine months Dominican producers had already lost 40 million dollars due to their inability to export to the USA.

As a preventive measure, the sterile fly release continued for several more months. If at any point, the presence of the medfly had been detected, the export ban would have been reintroduced. Once the sterile fly release stopped, surveillance continued another three months – three medfly life cycles – to make sure no flies were left.

A surveillance network against invasive non-native fruit flies, including medfly, has now been established at high-risk points of entry and quarantine actions have been strengthened. This will enable early detection and immediate response to any pest incursion, safeguarding the country's horticultural industry and the livelihoods of its farmers.

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MEXICO

Sterile insect technique curtails pest threat to Mexico's Opuntia cactus sector

When a cactus moth lays its eggs on an Opuntia cactus, it creates one of nature's most effective camouflages. The eggs emerge as what is called an "egg stick", because they look like the cactus spine. The problem is that when the larvae emerge from the dozens of eggs that make up the egg stick, they survive by eating – and destroying – the cactus leaf pads. The cactus moth is an invasive species native to South America, including northern Argentina, Uruguay, Paraguay and southern Brazil, but after its initial introduction to the Caribbean for research purposes, it expanded its range to the Caribbean islands and eventually to the Florida Keys off the US Gulf Coast. It also infested two islands off the Yucatan Peninsula, from which it threatened Mexico's enormous commercial cultivations of Opuntia as well as the arid ecosystems of the area that depend on Opuntia cactus for soil and wildlife conservation. The threat was enough to bring Mexico's Ministry of Agriculture, the US Department of Agriculture (USDA), the Joint FAO/IAEA Division and IAEA's Technical Cooperation Department together to implement an eradication programme to curtail the Yucatan infestation. However, despite its success, the moth threat remains.

The Opuntia cactus can be fried as a vegetable, eaten raw as a fruit, used as forage for livestock, added as an ingredient in botanical medicines, planted in rows as border hedges, or left to propagate in arid areas where it contributes to soil conservation and serves as a water or food source for wildlife. In Mexico, where this cactus is considered a staple food, some 300 000 tonnes are produced for consumption each year by 30 000 producers and another 28 000 are employed in processing and packing facilities.

Thus, when one invasive cactus moth was found in an Opuntia cactus on Mujeres Island off the coast of the State of Quintana Roo on the Yucatan Peninsula in 2006, alarm bells went off in Mexico City. Plant protection authorities immediately surveyed the island and found most Opuntia plants infested. Further inspection of the neighbouring Contoy Island also found infestations. Armed with this information, the Mexican Ministry of Agriculture took immediate steps to initiate an eradication programme before the moths could reach the mainland.

As it happened, there was already an existing technological package, including surveillance tools and the sterile insect technology, set to deploy. In the late 1980s, the United States had faced a similar infestation when the cactus moth was found in the Florida Keys – probably the result of an infested shipment of ornamental plants that had arrived from the Caribbean

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into mainland USA. When the moth was found in Florida, Mexico knew that its extremely important Opuntia cactus sector could be in the sight of the pest, so it joined forces with the USDA to combat an invasive pest outside Mexico's borders. It signed an agreement with the USA that included contributing financial resources toward efforts to combat the cactus moth in Florida and, in turn, keep the moth from moving along the Gulf Coast to Texas where it would pose a direct threat to Mexico.

Mexico adopts pest control measures used in Florida

The containment programme in Florida had been a success, so Mexico determined to follow a similar plan on the islands off Yucatan. This called for defining the area of the outbreak, setting out baited traps within the area, cutting back any infested cactus and eliminating Opuntia plants that could act as hosts to the moths, replacing them with ornamental plants. These initial steps served to greatly suppress the moth population on the two islands, after which the campaign employed the sterile insect technique (SIT). This meant bringing to Mexico sterilized moths that had been reared in Florida for the US cactus moth containment campaign. The moths, which had been sterilized by exposure to gamma irradiation, were released over the infested areas in the islands. With SIT, the sterilized males mate with the wild females and produce no offspring, which is the final step of a pest eradication process.

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By October 2009, when three life cycles of the pest had passed without any further detection, the cactus moth was officially declared eradicated. The work of the Mexican Ministry of Agriculture, the USDA, the Joint FAO/IAEA Division and IAEA's Technical Cooperation Department avoided significant damage to the economically important cactus and prickly pear industries, and to the Opuntia arid ecosystems. If the moths had made it to the mainland – where some 150 000 ha of cacti are cultivated for fodder, 60 000 ha for production of prickly pear fruit, 10 500 ha for the Opuntia leaf vegetable and another 3 million hectares are covered with wild Opuntia – the results would have been economically, socially and environmentally devastating.

Since the eradication was declared, Mexico has continued the comprehensive surveillance programme at high-risk points of entry, which puts it in a good position for early detection and emergency response if the cactus moth enters Mexican territory again. Mexico has also continued its cooperation with USDA to prevent entry into Texas and to the north-eastern states of Mexico. The USA concluded its SIT release programme in 2012 but remains vigilant in efforts to contain any further spread of this potentially devastating invasive pest.

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SENEGAL

Productive cattle breeds thrive in Senegal's Niayes region as a result of tsetse suppression

In Senegal, as in many other parts of West Africa, African animal trypanosomosis (AAT), a deadly disease carried by the tsetse fly, has long been a major obstacle to the development of more efficient and sustainable livestock production systems. For more than 50 years, the Government of Senegal invested in importing more productive improved breeds from Europe and elsewhere, but many did not survive because they had no natural tolerance to AAT. Now, thanks to a long-term government-executed tsetse eradication programme in the 1 000 km^2 Niayes region of Senegal, tsetse flies have been eliminated in all but one hotspot area, AAT is no longer an issue and imported herds are thriving.

The frequency of the deadly African animal trypanosomosis disease transmitted by the tsetse has dropped dramatically in Senegal's Niayes region since the pest population was suppressed by a long-term government-executed tsetse eradication campaign that involved the release of sterile tsetse flies. Before the eradication project's success, most farmers reared only local cattle breeds, 80–90 000 heads of which live in the area. These cattle had low milk and meat production and low reproductive rates but the farmers kept them because they were also naturally tolerant to trypanosomosis, which meant they could survive there. Today, the suppression of the tsetse population is allowing farmers to replace the low producing local cattle with more productive exotic breeds.

With tsetse under control, the government is now working closely with the farmers, giving money to a newly formed farmers' association so that farmers can buy the exotic animals themselves. The results have been so positive, the farmers are adding their own money to what the government provides and are now buying and importing ten times more cattle than before. And, because they are purchasing more and transporting them by boat instead of air, the cost has dropped to half or a third of what they were paying before. Working together, farmers in the region are progressively replacing their indigenous cattle that produce only 1–2 litres of milk a day with exotic cattle that produce between 20 and 40 litres a day and, hence, substantially increasing both productivity and income.

Ecological islands provide opportunity for tsetse eradication

The Niayes region is actually an ecological island with a coastal micro-climate that is well suited for high-producing exotic cattle breeds – and it has now also

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proven a unique area for this type of pest eradication project. A feasibility study for the tsetse eradication campaign, supported by the Joint FAO/IAEA Division in 2006-2010, found that the tsetse habitat in the area was extremely fragmented. Flies were present in small pockets, though often at high density and, most importantly, the study confirmed that the tsetse populations in Niayes were isolated from the main tsetse belt in the southern part of Senegal by dry areas where the fly could not survive. This meant that, once eliminated, the risk was low that the area would subsequently be re-infested with flies from other parts of Senegal.

Much credit for the success is given to the adaptive management approach of the project, which called for monthly project coordination meetings with the many different stakeholders, for transparency at all levels and for decision-making by consensus, with decisions for moving the project ahead based on scientific principles.

The eradication programme followed the area-wide integrated pest management approach that used insecticide-impregnated traps, pour-on insecticides and nets for the initial suppression of the tsetse population, before applying the sterile insect technique (SIT) as the final component. This technique involves the release of mass-reared, sterilized male flies into the area to mate with wild females that therefore produce no offspring. At the time of reporting, the incidence of the disease is close to zero and flies have been eliminated in all but one hotspot area. Nevertheless, the release of sterile tsetse flies will continue for several months in order to tackle any potential residual fly pockets and ensure that absolutely no wild flies remain.

A cost-benefit analysis of the tsetse eradication programme in the Niayes found that the costs of the tsetse eradication programme, estimated at €6 400 per km^2, was substantially outweighed by the annual additional income to farmers, who replaced their local breeds with exotic ones, of €2 800 per km^2, because they would save the cost of treating animals and have more profit from selling milk and meat. The eradication project would therefore pay for itself in less than 2½ years. Furthermore, the improved milk and meat production of the exotic breeds will enable farmers to increase their income also with smaller herds, which in turn will reduce the grazing pressure on this already fragile ecosystem.

Looking to the future, several countries are considering plans to set up similar programmes in other areas. A genetic study, covering all of West Africa, has identified ten tsetse-infested potential ecological islands, which will be able to take advantage of what was learned and accomplished in Niayes.

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INDONESIA

Mutant rice varieties help Indonesia reduce rice imports

The village of Gowa in the South Sulawesi province of Indonesia has an agrarian history that dates back to the fourteenth century – an agricultural prominence it still maintains, in part due to the top-grade fertile soil in the region. In fact, the area is now serving as a centre for the introduction of new mutant rice varieties that owe their existence to nuclear technology. Through the combined expertise of the National Nuclear Energy Agency of Indonesia (BATAN), the Joint FAO/IAEA Division and PB Salewangang, a certified seed breeding company, 18 Gowa farmers have planted their land exclusively with six new mutant rice varieties. But these farmers aren't growing the new varieties as a food crop. They are using BATAN's breeder seed material in their fields for seed multiplication. Once multiplied, PB Salewangang distributes seeds to other farmers interested in planting the new varieties to take advantage of their improved yield and quality.

Although Indonesia is the world's third largest grower of rice, it still must import rice almost every year, mainly to keep reserves at a safe level. The main reasons for the gap can be traced to farmers using non-optimal production techniques and to the fact that each person in the country consumes an average 150 kg of rice per year – an extremely high consumption rate. In addition, smallholder farmers, with less than 0.8 ha of land, account for 90 percent of Indonesia's rice production and so cannot take advantage of economies of scale in their production.

Indonesia encourages technological innovation in its goal of reaching self-sufficiency in rice production. In addition to promoting improved rice infrastructure, including irrigation planning, it also supports the plant mutation breeding work of the National Nuclear Energy Agency of Indonesia (BATAN). BATAN has a long history of success, breeding crop varieties that bring higher yields to meet the needs of Indonesian farmers. Now, it is expanding this success – still breeding for yield but also focusing on specific quality parameters, meaning that it seeks varieties that have the taste and texture that consumers are increasingly looking for.

Mutation breeding adds 3 275 varieties to the world's food basket

Since the 1970s, BATAN has worked very closely with the Joint FAO/IAEA Division and has received both state-of-the-art equipment and extensive training

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in the implementation and use of mutation breeding technologies that improve and speed up the process of mutation breeding. Indeed, the Joint Division has promoted the worldwide use of plant mutation breeding since its inception in 1964. As of March 2018, people around the world were benefitting from 3 275 officially released mutant varieties of 214 different plant species, 50 percent of which are cereals and 15 percent are legumes. The process itself calls for exposing seeds to gamma irradiation, which generates random genetic variations. Those variations that display the desired characteristics are then subject to further testing and breeding.

To date, BATAN has developed 23 mutant rice varieties. It typically contracts with certified seed breeding companies that multiply the seeds for dissemination and then market the new seeds to farmers, hosting harvest fairs to introduce farmers to the advantages of adopting the new varieties.

PB Salewangang, one of Indonesia's most respected producers of certified seed, chose farmers in Gowa, in South Sulawesi, to multiply the seeds of six of BATAN's latest mutant varieties. This area was chosen because, while it has top-grade soil, farmers there do not really prosper as they should, mainly because they have insufficient supply of good quality rice seeds that would ensure high yields and a profitable return.

In 2016, those farmers growing BATAN's new Sidenuk, DiahSuci and Mira-1 rice varieties had a 150 percent increase in yield compared with conventional paddy seeds, and were indeed able to supply 3 percent of the seed required by the entire South Sulawesi province. The success inspired other farmers to use the company's seeds.

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In 2017, the company chose 18 farmers to plant six mutant varieties and, with the March 2018 harvest, the six varieties had averaged a 50 percent increase in yield.

These new rice mutant varieties are especially important today because they are adaptable to climate change variability. Already, 4.7 percent of Indonesia's rice fields are cultivated with high-yielding mutant varieties of rice. This means that 800 000 farmers are involved, and they are producing enough rice for 20 million people. BATAN recognizes the value of these high yielding varieties and, in collaboration with some local governments and the Ministry of Agriculture, it has established Agro Techno Parks (ATPs) in some provinces which are expected to become centres of excellence for developing certified seeds of mutant varieties and related technologies to support food production under climate smart agriculture.

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PAKISTAN

Mutant varieties satisfy market and add USD 6 billion to Pakistan's economy

When Pakistani farmers harvested fields planted with a new mutant variety of cotton, not only did they have a higher yield, they also received a higher price at the market because of the improved fibre quality. Farmers who adopted mutant varieties of sesame released in 2016 saw yields double and income increase, and now these new varieties cover 50 percent of the area planted to sesame in the entire country. Those who planted a mutant variety of castor bean released in 2017, bred for early maturity and high oil content, have already planted it on 2 000 ha and are making an extra USD 618 per ha. These are just a few of dozens of advances made possible by Pakistan's Nuclear Institute for Agriculture and Biology (NIAB) which, with the support of the Joint FAO/IAEA Division, has used mutation breeding to improve varieties of eight different crops – benefitting millions of Pakistani farmers and their families, and adding billions to the Pakistan economy.

Across the millennia, those entrusted with saving seeds for planting in future seasons have always made decisions related to the environment, choosing seeds from varieties that will give them the best chance of a good harvest. Even as science has advanced the field from simply saving seeds to cross breeding and now to mutation breeding, the crucial role of the plant breeder has remained largely unchanged – developing varieties that can thrive in whatever the local environment has to offer and be resilient enough to adapt to change. Since 1969, Pakistan's Nuclear Institute for Agriculture and Biology (NIAB), an institute of the Pakistan Atomic Energy Commission, has overseen the development of 43 mutant crop varieties, ranging from sesame seed to castor bean to mandarin to cotton – all bred in response to what Pakistan's farmers and their consumers need.

The government of Pakistan recognizes the importance of breeding crop varieties specifically for the Pakistan situation – its terrain, its climate, the needs and capacities of its farmers and, of course, when it comes to food crops, the taste and texture that will appeal to consumers. This government support of the NIAB mutant breeding programme has paid back in terms of increased yields and higher quality products, which have not only contributed to farmers' livelihoods, it has meant more food for the marketplace and improved food security. Two sesame varieties released in 2016 and 2017 have double the yield of traditional varieties and are more suitable for modern cultivation techniques. The mutant mandarin variety, NIAB Kinnow, released in 2017, has an increased yield of more than 30 percent and reduced seed count from around 50 to just 3-5 seeds per fruit, which makes it more valuable and popular for export.

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Breeding for taste and texture as well as yield

NIAB has received support from the Joint Division for more than 30 years, including equipment and technology packages for mutation breeding, individual staff training through fellowships, and national and regional training courses. The mutation breeding process calls for irradiating and then planting crop seeds, and then screening them as they grow in the following generations to see which induced changes that emerge could be helpful for breeding in future generations – from aesthetics of colour and texture to physiological changes that account for traits such as heat or cold tolerance, resilience or length of the growing period.

With its overall goal of supporting NIAB in improving local varieties, the Joint Division has included NIAB in three regional projects in Asia, for cotton, rice and green crops. NIAB staff members serve as experts to support national and regional technical cooperation projects and participate in the Joint Division's coordinated research projects (CRPs).

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Staff members also attend general training courses, on topics such as breeding protocols developed by the Joint Division, and have attended specialized training on topics such as drought tolerance and disease resistance in rice with the International Rice Research Institute (IRRI), mutation breeding for development of heat tolerant cotton mutant varieties, and breeding for green crops in Pakistan focused on climate-smart agriculture.

Cotton of course is a cash crop, important for the textile industry in the region, which has made it a priority for NIAB's mutation breeding activities. Right now, of the 3.1 million hectares planted with cotton, between 15 and 25 percent are planted with mutant varieties, a number expected to increase to 30–40 percent in 2018–2019. Three mutant varieties released in 2013, 2016 and 2017 have been well accepted by the farmers because of their ability to withstand high temperatures and heavy rains, resistance to pests and diseases, and their capacity to sustain yields in this time of climate change while also producing a very high-quality fibre that brings a higher price than standard varieties at the market.

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These results of NIAB's work with the Joint Division demonstrate that modern and advanced nuclear techniques contribute to major improvements in agricultural output in both quantity and quality, which is especially important considering that the livelihoods of 80 percent of the Pakistani population comes from agriculture. The improved characteristics of the mutant varieties have not only improved the agriculture sector's output and, in turn, national food security, they have also contributed to the economy of the country. The cotton mutant variety NIAB-78 alone created an additional income of USD 486 million to often poor growers between 1986 and 2004. NIAB estimates that the 43 NIAB mutant varieties had an economic impact on the national economy that, as of April 2018, amounted to USD 6 billion.

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SRI LANKA

Sri Lankan farmers benefit from mutation bred groundnut for 25 years

The year was 1993 when the groundnut variety Tissa, a product of mutation breeding, was released in Sri Lanka. As far as plant breeding is concerned, 25-year-old varieties are often ancient history – part of the past. Usually, new varieties are well received when they are released but as plant breeders continue to develop new improved varieties to meet new needs, the farming community also moves on. However, for the 1993 Tissa groundnut, it's a different story. It remains by far the most popular groundnut variety among Sri Lankan farmers, who chose it for 80 percent of their groundnut plantings, consider it a cash crop and have seen their groundnut income increase 5 percent. Sri Lanka started its mutation breeding programme in the late 1960s with the help of the Joint FAO/IAEA Division that has continued to provide equipment and training. To breeders, Tissa was such a success that they now use it to breed new and even better groundnut varieties.

In Sri Lanka, where agriculture is the most important sector of the economy, nearly 82 percent of the population lives in rural areas and agriculture accounts for 30 percent of national employment. Although rice is by far the major crop for the country, about 5 percent of the farm families in Sri Lanka earn extra income growing and selling groundnuts. While not a main ingredient of Sri Lankan cuisine, groundnuts are often found in curries and fried rice, or roasted to be eaten as snacks. Farmers also benefit from a trend towards production of value-added groundnut products in the confection and snack industries, while still taking advantage of their traditional markets which include selling their groundnuts as an oil crop and as animal feed.

For the past 25 years, farmers in Sri Lanka have overwhelmingly chosen Tissa, a groundnut variety developed in the 1990s through irradiation of a Viet Nam groundnut. One element of this success undoubtedly stems from a survey that the breeders performed to determine what characteristics groundnut farmers and consumers would want from an improved groundnut variety. Based on input from farmers, they selected for disease resistant, drought tolerant and high-yield lines, and with the Tissa variety, they also selected a lower shell ratio and a 40 percent oil content. Tissa also has a short growing season, which means that it can be planted as an extra crop, often between rice seasons, with minimal land preparation and few inputs.

Screening mutants for desired traits

Working with the Joint FAO/IAEA Division, the Sri Lanka Department of Agriculture started mutation breeding in the late 1960s, using gamma irradiation to induce mutations. Nuclear techniques such as the use of

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gamma irradiation for inducing mutations in combination with related biotechnologies is an efficient and safe tool in breeding programmes for crop improvement and suitable to support efforts to enhance crop productivity. Enhancing crop productivity for sustainable food security is becoming an increasing issue in many countries as the effects of climate change and increasingly erratic weather events on agriculture are reducing the productivity of existing local varieties. Mutation breeding takes advantage of genetic variability for developing, for example, drought- and disease-resistant varieties as well as myriad of other desired traits.

Sri Lanka released its first mutant variety – a high yielding mutant rice – in 1971. Known as MI 127, it was widely adopted and contributed 5 percent of import savings of rice. This success was followed by other mutant varieties of sesame, rice, tomato and groundnut. The country has participated in many Coordinated Research Projects and national and regional technical cooperation projects, conducted with the Joint Division to enhance human capacity and build infrastructure for the genetic improvement of crops using mutation breeding.

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In recognition of its numerous successes in plant mutation breeding and of its ongoing endeavours to develop further sustainable crop varieties, the Sri Lanka Department of Agriculture was awarded the prestigious Achievement Award by the Joint Division in 2014. In 2016, the Joint Division joined in establishing Sri Lanka's National Centre for Nuclear Agriculture and provided a new cobalt-60 source, through the IAEA's technical cooperation programme, to broaden the mutation breeding programme by making it available to any commodity research institute in the country.

In the 25 years since mutation breeders in Sri Lanka developed the Tissa variety, Sri Lankan farmers have continued to plant and benefit from it. Not only have farm families been able to increase their income over this period by an average of 5 percent per year, with this variety the country has also been able to largely meet its own groundnut requirements.

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BRAZIL

Brazil farmers plant legumes as mini-fertilizer factories

Organic farming has experienced extremely rapid growth in Brazil in recent years, with plantings of organic vegetable crops on almost 1 million hectares in the 2016–2017 season. This growth is expected to continue, in part because of the sector's ability to plant and tap fields of legumes as a natural source of non-chemical fertilizer. Known as biological nitrogen fixation, the process has been researched and promoted by the Joint FAO/IAEA Division for many decades and has been widely implemented in Brazil. These efforts have helped make nitrogen fixation a leading farming practice of many soil management systems.

In order for agricultural production to be certified as organic, crops must be grown without chemical fertilizers. In the past, organic farmers in Brazil faced low supply and high cost of the typical non-chemical fertilizers, such as oilseed cakes made from beans or cattle manure. As an answer to that problem, they are now taking advantage of legumes – which can supply natural nitrogen fertilizer to organic cash crops.

All living things need nitrogen to survive. Humans and animals are able to take in nitrogen from the air; most plants can only absorb nitrogen from the soil. Thus, the expensive commercial nitrogen fertilizers, if not used properly, can evaporate into the air as a greenhouse gas, which then contributes to climate change, or leach into the soil, polluting water supplies. Legumes offer a way to greatly decrease these side effects. The nodules on their roots act as mini-factories – and the factories' output is nitrogen-rich fertile soil.

It all starts with planting a field of legumes. Through a biological process, the nodules on the roots are able to capture nitrogen from the air, which enables the plant to grow. When the legumes are harvested, not only does the yield provide food and income for the farmer, it leaves nitrogen-rich residue behind in the field. As that residue decomposes, the nitrogen in the nodules become incorporated into the soil as a natural fertilizer – a green manure – that will be there to nourish the next crop – meaning the farmer will be able to use less or even no chemical fertilizer for the next cropping season.

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From indigenous knowledge to scientific understanding

Although farmers have long recognized that planting certain crops would improve soil fertility, they didn't understand why and they didn't know the best way to take advantage of this natural phenomenon. Since the 1970s, the Joint FAO/IAEA Division has focused on improving the process of nitrogen fixation and thereby farmer's success, working through national and regional field projects and coordinated research projects to identify the most suitable legumes for different regions and agro-ecosystems of the world, and then disseminating the technology through training, fellowships and workshops. Using nuclear tracing

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methods based on the nitrogen-15 isotope, they have also studied the impact of chemical fertilizers and, in turn, provided farmers with information on how to use them more efficiently and economically without fear of unduly harming the environment.

Through its work, the Joint Division has helped make nitrogen fixation an important part of soil management systems. It now supports an international network of scientists who share information and promote these natural, no-cost bio-fertilizers across the spectrum of agricultural systems.

In 2016–2017, Brazil's total grain production reached 230 million tonnes on 58 million hectares. Of that, almost 1 million hectares were farmed as organic, and that number is expected to increase. It is estimated that less than 20 percent of the nitrogen used by plants in Brazilian agriculture comes from chemical fertilizer and the rest from nitrogen fixation, particularly from soybean fields. Considering that the natural nitrogen can remain in the field for up to two planting seasons, farmers can intercrop, growing non-legume crops in alternating seasons to take advantage of the nitrogen that has been left behind.

This translates into enormous savings. Each year, Brazil's farmers are able to use 7.5 million tonnes of natural nitrogen that comes from nitrogen fixation. That equals a savings of USD 13 billion, because that's what it would cost to buy the same amount of chemical nitrogen fertilizer. In addition, farmers who employ nitrogen fixation have healthier soils and can greatly decrease the expense of purchasing chemical fertilizer. And with that, the risk of emission of greenhouse gasses and the fear of water pollution is reduced. It is a win-win for the farmers and the planet.

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CHINA

Rice fields in China double yields by "ratooning"

Just as grass lawns regrow after they are mowed, rice fields can regrow after they are harvested. This second harvest – known as a ratoon crop – has traditionally yielded only a small fraction of the first harvest. But farmers in China are now benefitting from laboratory and field studies conducted by the Joint FAO/IAEA Division that used nuclear techniques to determine the best rice varieties and the best fertilizer regimes for increasing second harvest yields, often resulting in second harvests as large as the first – meaning the farmers who ratoon correctly are doubling their yields – and their income.

The word "ratoon" meaningfully can be traced to two Latin words: *retonsus* which means "to cut down" and *retono* which means "to thunder back". It's meaningful because when ratoon is used in relation to agriculture, it means both: a crop is "cut down" at harvest, but its roots are left behind and from that stubble, a second crop "thunders back". Although, realistically, it's only been recently – thanks to an increased focus on fertilizer management and plant breeding – that the second "ratoon" crop has returned with any kind of thunderous energy.

Not all crops can regenerate. For example, maize cannot produce a second crop, but sugarcane, sorghum, pigeon pea and, importantly, rice can. The Joint FAO/IAEA Division began working on improving the outcome of rice ratooning – also called "stubble cropping" – in China's Fujian Province in 2012. This included studying fertilizer and water management practices for Jiafuzhan, an early maturing rice variety developed by Chinese plant mutation breeders.

Appropriate fertilization: for economic and environmental results

In addition to working with China's mutation breeders to develop and promote climate-resilient early-yield varieties, the Joint Division used nitrogen-15 stable isotope tracing to determine the optimum application rate for nitrogen fertilizers. Both the nitrogen-15 technology and the mutation induction for developing improved varieties were monitored and fine-tuned in the Joint Division's Agriculture & Biotechnology Laboratories in Seibersdorf, Austria, and then applied in the farmers' fields.

The nitrogen-15 technology was able to discern how well the main crop had absorbed the fertilizer, how much was left in the field after the first harvest, and how much more would be needed for the ratoon crop. A major goal is to avoid over-application, which, in addition to being an unnecessary expense, could have environmental implications if the fertilizer is converted as a greenhouse gas and emits into the atmosphere or is washed away and becomes a water pollutant. In this

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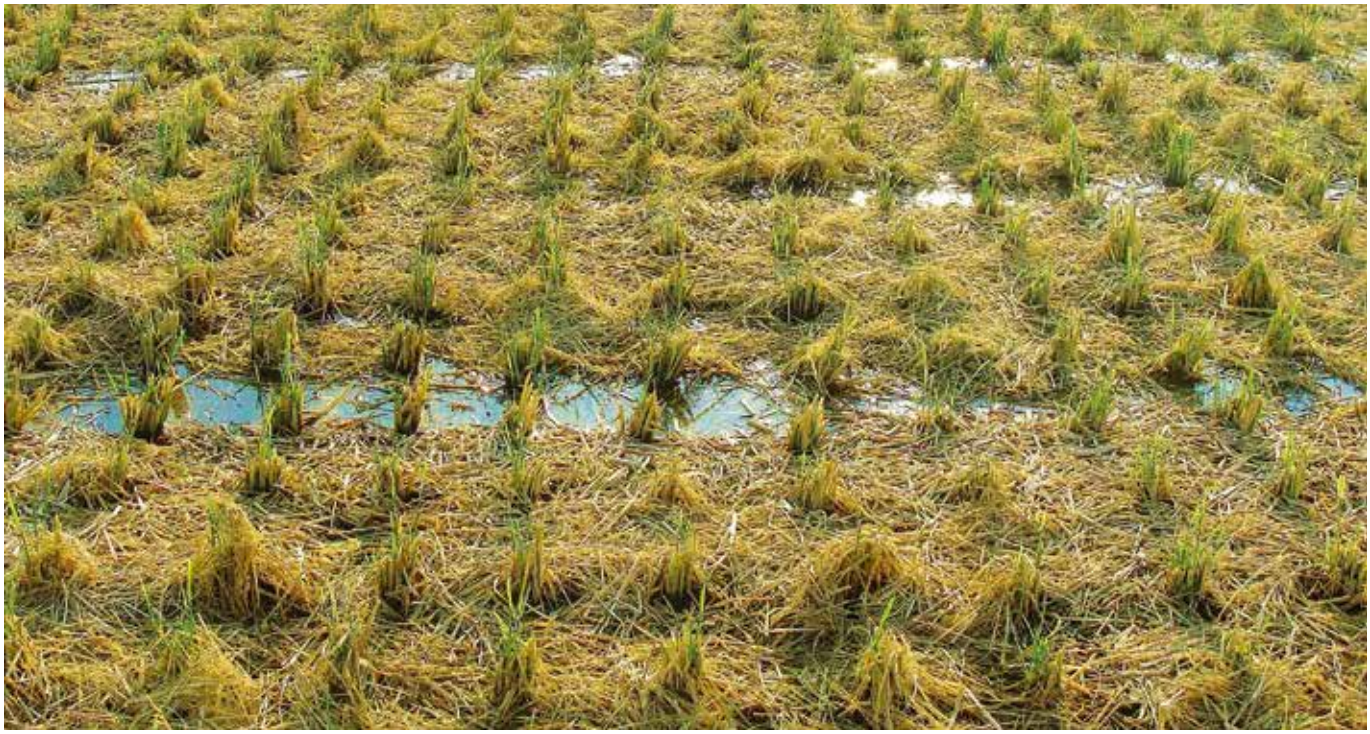

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study, the optimum fertilizer application needed for their ratoon harvest was 150 kg of nitrogen per hectare.

Efficient and economic ratooning requires developing and adopting crop varieties with high ratooning capability plus following the fertilizer management practices prescribed by the study. Success depends on the two being combined. The study found that farmers who adopted the combination of improved varieties and fertilizer management saw yields almost double from 6.7 to 12.3 tonnes per hectare. The only expense they incurred for the second crop was buying the required amount of supplemental fertilizer and the only labour required was having to spread the fertilizer, no replanting was needed.

Once the results were known, other farmers were eager to adopt the improved varieties and fertilizer management practices, and now ratooning is underway on 42 000 ha. In addition to nearly doubling rice yields, the farmers in Fujian Province saw their profits increase by USD 3 260 per hectare, which, combined with a 30 percent decrease in the cost of fertilizer, has proven extremely beneficial to the province.

In the past, many upland farmers had ratooned their rice crops, based solely on their awareness that a second harvest was possible. But their second harvest was much smaller than the first, sometimes dropping from 3 tonnes

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per hectare to 0.5 tonnes per hectare. At that time, they were happy even with a small second harvest. But now they know that with proper management, their ratoon crop can be almost equal to their main crop.

The success in China has indicated that improving ratooning yields also has potential for other rice-producing countries in Asia. They know what they will need: a rice variety bred for high ratooning capabilities, and nitrogen management which uses tracing studies to determine the amount of fertilizer needed to support a high yielding second harvest.

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PERU

Quinoa farmers increase yields using nuclear-derived farming practices

Once considered an orphan crop, the high-Andes grain "quinoa" has emerged from insignificance thanks to its well-deserved reputation for high nutritional value. Yet, this protein-packed grain also has a reputation for low productivity – which is not surprising, considering it often grows in harsh climates and terrains at elevations of several thousand metres. However, now, with results that have emerged from a Joint FAO/IAEA Division study that combines three different technologies, quinoa productivity can almost triple.

Although it was domesticated five millennia ago, quinoa is one of those foods that was practically unknown outside of Peruvian highlands until very recently when nutrition-conscious consumers learned of its richness in proteins, amino acids, fatty acids, vitamins and minerals. Once providing sustenance to the Inca civilization that flourished there in the thirteenth to fifteenth centuries, it was chosen as a food for NASA astronauts on space journeys in the twentieth century, and the United Nations declared 2013 the Year of Quinoa.

While all of this recognition is certainly positive, today's quinoa production also faces a harsh reality in terms of the frequent droughts, soil salinity, frost, hail, wind, flooding and abiotic stress present in the Peruvian Andes that add up to reduce its productivity. Because of both increased consumer demand and the importance of quinoa in the local diets, increasing production and yield stability have been identified as important challenges in addressing food security concerns across the Andean region.

In responding to this need, the Joint FAO/IAEA Division, working with Programa de Cereals y Granos Nativos, Universidad Nacional Agraria de LaMolina, Lima, Peru, developed an approach that incorporates three technologies: mutation breeding, isotope tracing and water control using a water-absorbing polymer. The study evaluated 63 improved quinoa lines in farmers' fields, specifically looking for their response to water and fertilizer. It also used nitrogen-15 stable isotope tracers to evaluate the optimum dose of nitrogen fertilizer needed to increase quinoa yields. And finally, it introduced the water-absorbing polymer, a foam product placed below the soil surface to keep water from running off the steep fields. The material soaks up rainwater, reserving it for the plant and, when the nitrogen fertilizer is applied, the uptake can be higher and, in turn, so the yield.

Techniques to improve quinoa production protect the environment

When combined, these technologies also protect the environment by holding the water, avoiding run off and

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retaining the fertilizer. so that it will not be washed away with rains and end up in water supplies or other places where it is not needed and its presence can be hazardous. The goal is for the plants to absorb most of the applied fertilizer to minimise leaching below the plant roots or being converted to greenhouse gas. There is also a financial saving for the farmer who needs to buy less fertilizer but still has a higher yield.

In this study, nuclear techniques were used to help define good management practices. Water-absorbing materials are a new entry into this type of farming, and their introduction will require training in its application and follow-up monitoring with nitrogen-15 tracing technology to ensure the nitrogen is being utilized efficiently.

Andean farmers are definitely benefitting from introducing these management practices, developed by the Joint Division and the Universidad Nacional Agraria de LaMolina,

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into their fields. Thanks to the improved quinoa varieties and good soil and water management practices, they have seen an enormous increase in yield, from 1.1 to 3.1 tonnes per hectare and, at the same time, they have reduced their fertilizer purchases by 30 percent and seen a 40 percent water saving. Quinoa farmers have already applied the new management practices on more than 14 000 ha. Looking ahead, the Joint Division plans to introduce these interrelated technologies and new management practices to Mexico, which has similar issues with its quinoa cropping.

Through good breeding and good water and fertiliser management, quinoa has gone from being an orphan to being a potentially valuable crop. And by increasing its yield almost three-fold, it is also improving health and food security of the people who have nurtured its seeds across the millennia.

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ZIMBABWE

Nuclear techniques help provide Zimbabwe children with healthy school lunches

In spite of the lack of water and poor soil fertility, the parents of students in two schools in two impoverished and arid regions of Zimbabwe were able to grow vegetables so that their children could go to school without empty stomachs. The parents and school officials received advice on how to manage the scarce water and improve soil fertility from a team put together by the Joint FAO/IAEA Division's counterpart in Zimbabwe. The food from the vegetable fields provided lunch for the children and excess produce paid for school fees – and the advice the team shared with the school and parents for creating the vegetable fields is now available for others in the community to adopt.

Students who attend two schools outside of Zimbabwe's capital city, Harare, often arrived for class so hungry, they could not concentrate. Some were reported to have collapsed from hunger during school assemblies. Others did not go to school at all, because their parents were not able to pay their school fees. When the headmasters of the schools approached the Joint FAO/IAEA Division's Zimbabwean counterpart and asked for assistance in establishing vegetable fields near the schools, the answer was "yes", and a team was established to support the project.

The schools had tried to initiate vegetable fields in the past, but had not succeeded due to the extremely harsh climate, arid conditions and poor soil fertility. In this part of Zimbabwe, it is difficult to have healthy gardens without irrigation. They also needed fertilizer, which is expensive and difficult to come by in the country. So, in accepting to help the schools with their fields, the team recognized the need to maximize resources and ensure their efficient use through small-scale drip irrigation.

The Joint Division had already been providing technical input to a regional technical cooperation project in 16 countries of Africa, focused on using nuclear techniques to establish protocols for the efficient use of small-scale irrigation systems. The national counterparts then showed local people how to determine the soil water situation and fertilizer needs, so that precious resources are not wasted.

Yields from school vegetable fields feed both students and their families

When the Zimbabwean counterpart agreed to help the headmasters establish vegetable fields, he and his

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team carried out studies in their research station in Harare to determine when and how much water would be needed for the various crops. They used both the neutron probe and nitrogen-15 stable isotope tracers – tools that had been recommended by the regional project – to help the schools set up their fields in the most resource-efficient way.

A neutron probe is a sensor that measures how much water is beneath the soil surface and that works well for dry and cracking soil. The nitrogen-15 stable isotope technique traces the path of applied nitrogen fertilizers and determines if it is actually taken up by the plants' roots and used efficiently. If fertilizer is not used correctly, it either remains in the soil and can be lost as a greenhouse gas that contributes to climate change, or it can be washed away, polluting water sources, not to mention that the overuse of fertilizer would mean that the funds used to purchase it were wasted.

In poor areas such as these, it is especially important to make the most efficient use of the purchased fertilizer. Once the decision was made as to the correct location for the vegetable fields, the school parents prepared the land themselves and carried out the planting. They planted kale, cabbage, onion and tomatoes and even sugar beans, which are considered important elements of a healthy diet. The counterpart continued to assist, providing advice on when and how much to irrigate, when and how much fertilizer to apply, and the best approaches to control pest.

Through this project, school parents have been able to harvest the produce to provide healthy lunches for their children at school and also for household consumption. And by selling what was left they can afford to pay for school fees. During the very first cropping cycle, the children had their school accounts credited – even before the produce was sold – because this new farming adventure was considered a surety for the funds being available. And surety that no child must learn on an empty stomach.

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MADAGASCAR

Return to traditional terracing improves farm production in Madagascar

In Madagascar, where farming has moved toward modern intensive agricultural practices in recent decades, a study has demonstrated that the country's farmers would be much better off if they returned to the traditional terrace farming of their ancestors. Using isotopic techniques to study erosion patterns of the island country's mountainous regions, where more than 30 percent of the agricultural area is already degraded, the Joint FAO/IAEA Division found that terracing systems could reduce soil erosion by 40 percent.

Astronauts once reported that Madagascar looked as if it were bleeding to death. Today, looking at a satellite view of the country makes it easy to see what they meant. The image shows reddish rivers and reservoirs – not filled with blood but with the country's red ferralitic soil that is eroding down the island's steep slopes, leaving agricultural land barren and adding sediment and its polluting nutrients of nitrogen, phosphorus and potassium to water systems.

Due to deforestation and improper farming practices, Madagascar, one of the world's poorest countries, loses more topsoil per hectare each year than just about any other country in the world. The soil itself is not particularly fertile and now it has to deal also with the impacts of climate change, such as drought, floods and unpredictable rainfall that further break down the soil structure and makes it more likely to erode.

In order to help Madagascar's farmers with conservation practices, scientists at the Institut National des Sciences et Techniques Nucléaires (INSTN-Madagascar) in the capital, Antananarivo, worked with Joint FAO/IAEA Division experts to address the problem and identify the country's most erosion-prone areas. The Joint FAO/IAEA Division assists countries in quantifying soil erosion rates and assessing the effectiveness of their soil conservation practices. In the case of Madagascar,

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this called for using isotopic techniques to investigate and compare soil erosion rates in terraced and non-terraced agricultural fields.

Fallout from past nuclear testing allows scientists to quantify and map erosion

Highly-sensitive nuclear techniques allow scientists to track certain atoms, such as caesium-137 and lead-210, in soil to determine the soil's movement and its conditions. Caesium-137 first came to earth as radionuclide fallout following atmospheric nuclear testing in the 1950s and 1960s. As it was not there before, and because it binds strongly to soil particles, it now can be used as a soil marker to ascertain and compare soil movements in the landscape. Lead-210 on the other hand is a naturally occurring fallout radioisotope that can also be used as a soil tracer.

In cooperation with the Joint Division and through the IAEA's technical cooperation programme, INSTN received the necessary equipment and its staff was trained in how to collect soil samples and measure their radionuclides content and analyse the data. With that analysis, they concluded that if farmers would apply the same agricultural practices as their ancestors – and create terraces – they could reduce run-off and, in turn, soil erosion in the country by up to 40 percent, when compared to non-terraced agricultural fields, and thereby retain at least 3 tonnes of soil per hectare every year.

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In addition to identifying key areas with high erosion and sediment transfer, fallout radionuclide methods also enable better targeting of soil conservation measures. This increases farmers' ability to control and mitigate soil losses caused by erosion and to mitigate its environmental impact.

While the story of Madagascar is dramatic, it is just a part of a global situation that each year sees as much as 36 billion tonnes of fertile soil being lost from world agricultural systems through soil erosion. In economic terms, the on- and off-farm soil erosion costs for farmers and the world's land systems are estimated at USD 400 billion per year. Hardly surprising that the Joint Division receives requests for technical support from numerous countries around the world.

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The Joint FAO/IAEA Division brings nuclear techniques to the 2030 Agenda for Sustainable Development

Nuclear and related technologies provide competitive and often unique solutions that help fight hunger, reduce malnutrition, improve environmental sustainability and ensure food safety and authenticity, thereby contributing to national, regional and global attainment of the 2030 Agenda for Sustainable Development.

The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, a true partnership between FAO and IAEA based in Vienna, Austria, coordinates and supports applied research through more than 25 coordinated research projects where over 400 international and national research institutions and experimental stations cooperate. It also supports more than 200 demand-driven national and regional technical cooperation projects to transfer these technologies to member countries. It operates the FAO/IAEA Agriculture & Biotechnology Laboratories, which perform applied and adaptive R&D and develop standards, protocols, guidelines, training and specialized services. It embraces five primary areas.

Animal Production and Health develops, validates and applies innovative nuclear and nuclear-derived technologies for local feed resources and feed optimization; animal genetic evaluation and integration to breeding; enhancement of animal reproduction; and early, rapid diagnoses and control of transboundary animal and zoonotic diseases.

Food and Environmental Protection works to improve food safety and quality, enhance food monitoring systems for contaminants, trace the origin of food, verify its composition and promote commercial use of food irradiation. It also helps strengthen preparedness to radiological emergencies affecting food and agriculture.

Insect Pest Control assists member countries in implementing environmentally-friendly and sustainable methods to control major insect pests of crops and veterinary and human importance, with focus on area-wide integrated pest management incorporating the Sterile Insect Technique to enhance food security and international trade.

Plant Breeding and Genetics assists member countries in the design and implementation of innovative and effective plant breeding programmes using radiation-induced mutation through, for instance, gamma rays and X-rays, mutation detection and pre-breeding technologies, to enhance food security and sustainable crop production systems worldwide.

Soil and Water Management and Crop Nutrition works to improve resource use efficiency by crops and in cropping-livestock systems, and to protect soil and water resources for sustainable and climate-smart agriculture. It also helps strengthen preparedness and response to nuclear or radiological emergencies affecting food and agriculture.

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