Sustainable Solutions

Ionising Radiation: Transforming Crops and Commerce in the 21st Century

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Introduction

Ionising radiation provides significant benefits globally for food security, pest control, and international commerce. Despite challenges related to public perception, infrastructure and technology needs, the economic and environmental advantages are substantial. Continued international collaboration and increased investment in these technologies are crucial to realising their full potential. This brief explores key applications of ionising radiation in agriculture and trade, and describes the primary obstacles and prospects for their broader implementation.

Benefits of Ionising Radiation

Ionising radiation has been used in agriculture and food safety since the 1950s. It has gained renewed importance as a mature, advanced technology for pre- and post-harvest applications. As food demand rises globally and climate change threatens production, radiation-based technologies are emerging as powerful tools, offering innovative solutions to enhance food security, promote sustainable agriculture, and facilitate international trade. The most commonly used isotope to produce ionising radiation is cobalt-60, which emits gamma radiation.

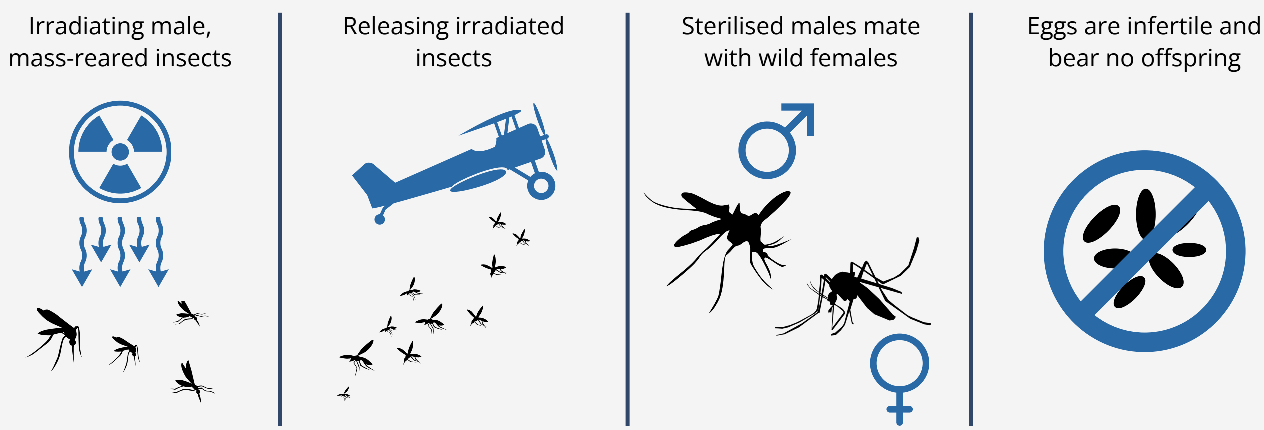
Ionising radiation can also be produced by electron beam (eBeam) and X-ray technologies, both of which need electricity to be able to generate radiation.

Supporting Agricultural Production

Sterile Insect Technique (SIT)

The Sterile Insect Technique is an eco-friendly pest control method using ionising radiation to sterilise male insects, reducing pest populations through unsuccessful mating. This technique is applied as part of an integrated pest management approach globally. The Guatemala-Mexico-US Moscamed Programme produces more than a billion sterile Mediterranean fruit flies (medfly) weekly, reducing and, in some areas, eradicating the medfly population in South and Central America.

In South Africa, the private sector programme X-Sterile Insect Technique (XSIT), supported by local citrus growers, the US Department of Agriculture, and the International Atomic Energy Agency (IAEA), helps control the false codling moth population, protecting the country's citrus industry and maintaining its access to international markets.



Sterile Insect Technique (SIT) application

Plant Mutation Breeding

Mutation breeding accelerates the natural mutation process by exposing plant matter and seeds to ionising radiation, leading to the development of improved crop varieties. In Bangladesh, this technique has played a pivotal role in boosting rice production. The availability of high-yield, drought-resistant, and heat-tolerant rice varieties has contributed to a threefold increase in rice output, ending seasonal famine in the northern region of Bangladesh. In Peru, mutation breeding has enhanced agricultural production in the face of extreme climatic conditions and the challenges of high-altitude farming. A notable success is the Centenario variety of amaranth, which was mutated to improve yield and salt tolerance. These applications of nuclear technology have significantly improved food security and the livelihoods of farmers in both countries.

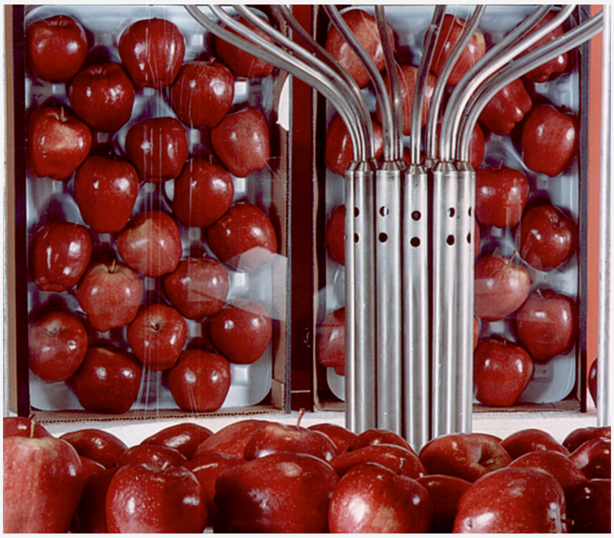
Food Irradiation

The irradiation of fresh produce, spices, and dried herbs makes food safe for consumption as it destroys bacteria that can cause food poisoning. It also extends the shelf life of produce by destroying spoilage organisms and suppressing sprouting. This is especially beneficial for perishable items like fruit and vegetables, as it allows them to reach markets in better condition, enhancing their value for consumers and ultimately reducing food waste. In Mexico, for example, radiation is used to extend the shelf life of mangoes for up to five weeks.

Phytosanitary Treatment

Phytosanitary treatment to ensure pest-free produce is a prerequisite for global trade. Ionising radiation is recognised as an effective post-harvest pest control method, playing a vital role in safeguarding domestic crops from invasive species that might accompany imported food products. As climate change drives insects into new territories, authorities are compelled to implement stringent quarantine measures, even within national borders. Using radiation for phytosanitary purposes not only facilitates international commerce but also helps maintain ecological balance and food security.

Novel barley variants created with irradiation
Credit: Kuwait Institute of Scientific Research



Phytosanitary treatment of apples using cobalt-60
Credit: US Government

Trade and Economic Benefits

The use of ionising radiation significantly advances trade and development in various ways. For example, the Sterile Insect Technique (SIT) has safeguarded agricultural industries in Guatemala, Mexico, Belize, and the United States from the medfly, boosting multibillion-dollar export sectors. In Peru, mutation breeding has led to the development of nine barley varieties, contributing $18 million annually to the national economy. As mutation breeding does not involve genetic modification, the resulting agricultural products are eligible for export to the European Union, which is a significant trading partner for many countries and maintains strict regulations on genetically modified organisms (GMOs).

Globally, over 60 facilities provide food irradiation services, enabling producers to meet international food safety standards. Recognising growth potential, private industries are investing in eBeam technology for food irradiation in countries like Pakistan and Mexico, enhancing exports of fresh produce and creating direct employment at these facilities as well as jobs in related sectors, such as logistics and manufacturing.

Environmental Sustainability

When ionising radiation is applied pre- and post-harvest, it not only bolsters food safety and security but also promotes environmental sustainability. SIT provides an eco-friendly alternative to traditional pest control methods, significantly reducing pollution by lowering reliance on chemical pesticides. Mutation breeding has led to the development of crop varieties that require fewer inputs, such as reduced water, fertiliser, and pesticide use, thereby fostering more sustainable and resource-efficient agricultural practices. Food irradiation further diminishes the need for chemical treatments and fumigation, effectively eliminating harmful microorganisms and pests without leaving chemical residues. By reducing post-harvest losses and minimising the need for chemical preservatives, irradiation enhances the efficient use of agricultural resources and supports safer international trade, especially for perishable goods.

IAEA Support

The IAEA, in partnership with the Food and Agriculture Organization (FAO), through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, leverages nuclear science and technology to enhance global food security and sustainable agricultural development. The Joint FAO/IAEA Centre helps countries to improve their agriculture and livestock productivity, natural resource management, food safety, security and nutrition, and to adapt to climate change. The recently launched IAEA-FAO Atoms4Food initiative highlights 60 years of collaborative expertise, showcasing how both organisations are leveraging nuclear science together to develop stronger, healthier, and safer crops.

The IAEA also supports Member States in establishing irradiation facilities and in managing radioactive sources. This includes guidelines for feasibility studies and the establishment of facilities, quality management, and safety and security programmes. Countries can also request IAEA assistance to enhance the physical protection of their gamma radiation facilities against potential security threats.

The IAEA delivers its support through mutliple channels:

IAEA Technical Cooperation (TC) Programme

The Technical Cooperation programme facilitates the transfer of nuclear technology and know-how to Member States, focusing on development priorities, such as health, agriculture, water management, and industry. It operates through tailored projects, expert missions, training, and fellowships, enhancing national development and promoting global scientific cooperation. The TC programme builds human and institutional capacity to ensure the safe and secure use of nuclear technologies. Every five years, a Country Programme Framework (CPF), prepared by a Member State in collaboration with the IAEA Secretariat, defines mutually agreed priority development needs and interests to be supported through TC activities. Each year, the IAEA Board of Governors sets the TC Fund target - €98 million in 2024 - to which Member States contribute their share.

Peaceful Uses Initiative (PUI)

The Peaceful Uses Initiative is a funding mechanism through which extrabudgetary contributions can be mobilised to supplement the TC Fund. PUI funds are used to support a wide variety of IAEA activities aimed at promoting broad development goals in Member States. The PUI also enables the IAEA to respond quickly to unforeseen emergency events, e.g., the COVID-19 pandemic, the Ebola virus in West Africa, and the Zika disease in Latin America and the Caribbean. Since its launch in 2010, the Initiative has received over €100 million in contributions and supported more than 200 projects in over 150 countries.

Seibersdorf Nuclear Applications Laboratories

The IAEA operates eight nuclear applications laboratories in Seibersdorf, Austria. These laboratories are a unique feature in the United Nations and focus, inter alia, on food and agriculture, human health, and environmental monitoring. Their activities respond to the development needs of Member States, conducting applied research, and providing training and technical services. The Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture operates five of the eight laboratories.

Safety and Security

The IAEA's Department of Nuclear Safety and Security plays a crucial role in global nuclear safety and security. It develops and maintains international safety standards and security guidance, assists Member States to implement robust regulatory frameworks, conducts safety and security reviews, and offers expert advice to enhance national infrastructures. It coordinates emergency preparedness and response activities, ensuring readiness for potential nuclear or radiological incidents. Through capacity-building initiatives, Member States' abilities to protect against nuclear terrorism and to secure radioactive materials are strengthened.

Coordinated Research Projects (CRPs)

The IAEA facilitates coordinated research projects, bringing together research institutions from developed and developing Member States to collaborate on research topics of common interest. CRPs provide tested and transferable techniques that contribute to areas, such as cultural

IAEA Fellows attending training on plant mutation breeding at IAEA Laboratories in Seibersdorf, Austria. Credit: IAEA

heritage, water management, health, agriculture, and industry. For example, there is a CRP focused on developing Striga-resistant crop varieties to combat significant crop losses in sub-Saharan Africa and semi-arid Asia, where over 300 million people are affected. This successful project enhanced human capacity and is expected to improve food security in Striga-prone areas.

IAEA Collaborating Centres

An IAEA Collaborating Centre is an institution, department, or laboratory in an IAEA Member State, designated by the IAEA to support other Member States with research, development, and training activities that align with the IAEA's programme. One example is the National Center for Electron Beam Research (NCEBR) at Texas A&M University, which promotes the adoption and adaptation of eBeam and X-ray technologies in developing countries. The NCEBR is collaborating with the Bangladesh Institute for Nuclear Agriculture (BINA) on financial and technical feasibility studies for the adoption of eBeam and X-ray technologies in Bangladesh. Another example is the Polish Institute of Nuclear Chemistry and Technology, which promotes the use of eBeam accelerators for food processing and sterilisation, offering services, such as joint research projects, training, and access to infrastructure.

Advancing Ionising Radiation: Opportunities and Challenges

The application of ionising radiation offers significant benefits for agriculture and trade, but requires substantial investment in infrastructure, regulatory frameworks, and operational expertise.

Historically, gamma radiation has been prevalent due to simpler operation and maintenance and suitability for countries with unstable power supplies or remote off-grid locations. However, radioactive sources have drawbacks: enhanced security requirements for high-activity sources, decreasing radioactivity over time, and growing costs and difficulties in obtaining replacement sources.

X-ray and eBeam technologies are emerging as promising alternatives, offering more opportunities for private industry investment with fewer regulatory concerns and reduced costs related to radioactive source management. These technologies also decrease dependence on volatile isotope supply chains. Ongoing improvements in eBeam and X-ray systems continue to enhance their efficiency, reliability, and sustainability. However, eBeam systems require stable electricity supply and a workforce of specially skilled operators and maintenance personnel to operate effectively.

Despite technological advancements, food irradiation faces challenges due to outdated regulations in many countries. These regulations, which often lag behind developments in irradiation technologies, limit the types of foods and doses permitted for irradiation, ignoring recent scientific evidence supporting its safety and benefits. This regulatory stagnation hinders innovation and prevents full utilisation of radiation for improving food safety, extending shelf life, and reducing food waste.

Public perception remains a challenge for food irradiation and plant mutation breeding due to safety concerns often based on misconceptions. Ongoing education and transparent communication are crucial to inform the public, retailers, and policy-makers about the benefits and safety of these technologies. Overcoming these challenges requires regulatory updates, industry engagement, and public education.

Gamma radiation remains the primary technology for SIT and plant mutation breeding. One of the initiatives to advance eBeam technology in this field is a collaboration between Texas A&M University and the Bangladesh Institute of

A farmer in Bangladesh, growing a higher-yield, more drought-resistant rice variety developed by BINA through plant mutation breeding with radiation. Credit: Nicole Jawerth/IAEA

Nuclear Agriculture on a technical and financial feasibility study on the adoption of eBeam and X-ray technologies in Bangladesh. One of the recommendations regarding the adoption and adaptation of eBeam technology in Bangladesh and developing countries in general is that, in order to be effective and sustainable, eBeam technologies cannot be parachuted into a country. These technologies require an indigenous ecosystem that would include building local capacity for their operation and maintenance and ensuring an adequate supply of electricity. In South Africa, X-ray is being tested as an alternative to gamma radiation for SIT. Challenges with scalability and electricity reliability remain.

A major hurdle in scaling up the use of radiation for agriculture and economic development is a lack of sufficient private and public investment in these technologies. A particular gap is that governments tend not to allocate official development assistance (ODA) towards creating essential infrastructure and capacity for nuclear applications in developing countries. Without additional resources, the IAEA, operating on a zero real growth budget, is limited in its ability to support Member States in creating a conducive environment for the successful adoption of radiation technologies.

Further Resources

For more VCDNP materials and events on ionising radiation uses, click **here**.

How Food Irradiation Works
U.S. Centers for Disease Control and Prevention

Mutation Breeding
IAEA

Sterile Insect Technique
IAEA

Case Study: The Contribution of Innovative Nuclear Technology to Sustainable Agriculture Development
VCDNP

Case Study: The Safe, Secure and Sustainable Application of Nuclear Technology in Industry and Agriculture
VCDNP

Balancing the Three Pillars of the NPT: How Can Promoting Peaceful Uses Help?
VCDNP

VCDNP
Vienna Center for Disarmament and Non-Proliferation

The VCDNP is an intenational non-governmental organisation that conducts research, facilitates dialogue, and builds capacity on nuclear non-proliferation and disarmament.

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