Atoms for agriculture

Both soil quality and the attention of pests can affect crop yields greatly and good livestock production needs good animal health. Murdoch Mactaggart **learns of innovative approaches to monitoring and managing such issues.**

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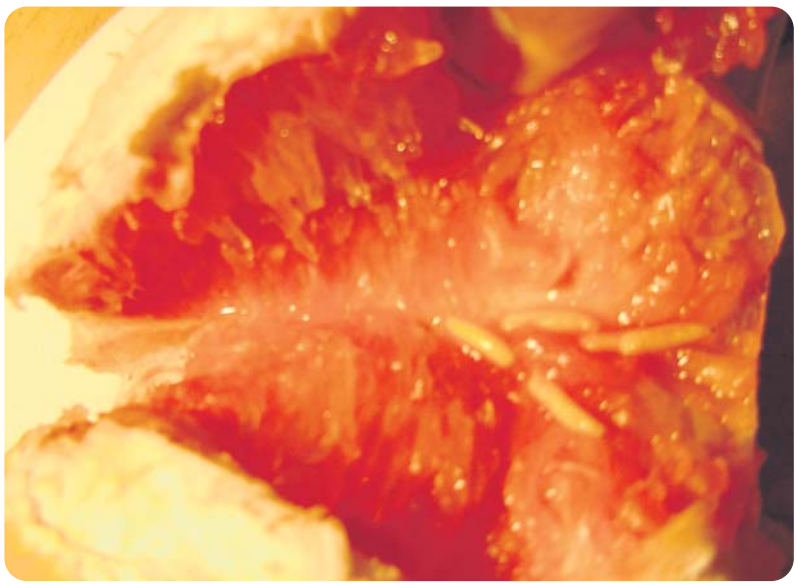
Food wastage and loss is a significant problem worldwide, reaching around 30%. In the west much of this occurs in the home, too often because consumers nervously throw out perfectly wholesome food older than some marked date but also because food has genuinely deteriorated excessively.

In developing countries, in contrast, spoilage or loss typically occurs before foods even get to market, perhaps on account of attack by various field or warehouse insect and other pests. Both livestock and crops are affected and the consequences for the economic and social well-being of such regions are considerable.

While it's necessary to educate consumers to evaluate food sensibly, there's also a need to reduce genuine food spoilage, whether in the larder, warehouse or field. Using radiation is an innovative approach to tackling this problem and one which has been growing in application. Radiation is, of course, an important part of healthcare, whether in the form of medical imaging, such as with X-rays, or in treatments such as radiotherapy.



Decomposition of food occurs as a consequence of the activity of bacteria, yeasts or moulds, often already present in the food itself. Irradiating products before sale prevents the micro-organisms concerned from reproducing and so reduces decomposition greatly. "We know that the general public is very sensitive so far as food irradiation is concerned" says Gerrit Viljoen, Head of the Animal Production and Health Section of the FAO/IAEA Joint Division, "but the food itself is not radioactive. It's been treated with a radioactive source to make it safe but there's no danger there."

The Joint Division (see sidebar) works closely with the national agricultural research institutes of its various member states, linking through them with local farmers to learn of and address problems around food production, both arable and livestock based.

"Our work is driven by demands from our member states." explains Director, Liang Qu, "When we've successfully developed a solution to a problem we transfer the technology to the member states concerned. We work for the public good – the beneficiary of our research should be particularly the poor farmer and the poor people in the developing countries."

Birth control for pests

One very successful pest control approach using radiation is the sterile insect technique (SIT). Insecticides have their place they also have unwanted side effects ranging from leaving chemical residues on produce, becoming ineffective as resistance develops in target species, through to killing beneficial insect populations. SIT takes an ecologically sensitive approach whereby large numbers of male insects are mass produced and irradiated to make them sterile but are otherwise unharmed. Released into the wild they mate normally but no young are born and the relevant insect population declines dramatically.

"There was a lot of success in using SIT to control screw-worm in the US and this led to the US working with partners in Mexico and elsewhere in central America to suppress and finally eradicate screw-worm there." says Katherine Long, Programme Officer with the Joint Division. "This led to continuing research on other insects. Not all insect pests are suitable candidates for the sterile insect technique but we've had a lot of success, especially with the Mediterranean and other fruit flies and with some tsetse species."

Fruit flies destroy fruit and vegetable crops world-wide. Establishment of the Mediterranean fruit fly in California alone would cause, it's estimated, production losses and control costs of over $1.7 billion annually. Tsetse flies have existed for at least 34 million years, are primarily pests of sub-Saharan Africa and vectors of serious diseases such as sleeping sickness in humans or nagana in livestock. The Joint Division is also researching using SIT to control mosquitoes and hence limit the spread of malaria.

A related technique is 'inherited sterility' and is particularly applicable to moth control. Here specialised factories breed large numbers of different target species of moth, treating the males with sub-sterilising doses of radiation before releasing them into the wild. As with SIT the males mate normally but in this case father very few offspring, nearly all of them sterile males, so that the moth population steadily declines.

"Mutation induction is simply a matter of accelerating the mutation process so that we can rapidly identify favourable mutations and breed from them."
Liang Qu

Mitigating climate change

"Another big issue for us is addressing the impact of climate change." adds Long. "In both crop and livestock production we're looking at how we can increase productivity while using less arable land or other resources."

Throughout much of Africa and Asia soil erosion and degradation is a serious problem and part of a vicious cycle as degraded soils lose water rapidly, yields drop, and protection against flash floods vanishes, further increasing degradation. In China, however, a World Bank project in Yan'an, used radionuclide soil measurement techniques developed by the Joint Division to identify and measure soil improvement approaches, including terracing, contour cultivation and planting of grass and specific shrubs. Erosion rates reduced by between 16% and 80% and brought an overall reduction of topsoil erosion of some 77% within six years.

In Peru, in climatically adverse condition high in the Andes, a different technique, mutation induction, led to the development of a barley bringing yield increases of up to 150%, so improving farmer incomes by around 30%.

"Mutation induction is simply a matter of accelerating the mutation process so that we can rapidly identify favourable mutations and breed from them." explains Liang. "It's quite unlike the GMO process, which introduces foreign genetic material, but simply speeds up the natural, spontaneous mutation of a crop to bring desired improvements."

Improving animal health

The nuclear tool chest used for monitoring and improving animal health is perhaps particularly impressive and includes nuclear immunoassays and molecular techniques as well as using isotopes to label and trace proteins and nucleic acid molecules, both to detect harmful pathogens and to monitor different treatments or feeding regimes.

"The eradication of rinderpest is an important success story in which the Joint Division played an important part." adds Viljoen. "Member states affected requested help and because the economic and other impacts of the disease were so huge a wide range of international organisations were involved. Now there's been no reported case of rinderpest since 2003 and in 2011 we expect a joint declaration from the FAO and the World Organisation for Animal Health that rinderpest has been finally eradicated. We estimate the saving to Africa alone at around $1 billion annually."

The Joint Division points out strongly that its work reflects the remit of the IAEA to use nuclear technologies for peaceful purposes while its focus on improving agricultural yields directly connects with that of the FAO itself seeking to eradicate hunger worldwide.

"Our aim is to improve food security and food safety, perhaps particularly in the areas of global poverty and hunger." adds Liang.

Cooperating to improve agriculture

The genesis of International Atomic Energy Agency (IAEA) lies in the "Atoms for Peace" address made by then US president Eisenhower to the UN General Assembly in 1953. In 1957 the IAEA was established as an autonomous, intergovernmental organisation with the remit of promoting the peaceful use of atomic energy and inhibiting its use for military purposes. Its partner in the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, the Food and Agriculture Organization of the UN, (FAO), is a specialised agency of the UN, established in 1945 with the aim of leading efforts to defeat global hunger.

As each body had its own relevant division it made sense to bring together their separate financial and research resources into a joint division and this was done in 1964 with the aim of researching techniques using nuclear technology to improve food security and food safety. The Joint Division, which has its own agriculture and biotechnology laboratories, works for the public benefit through its member states, typically responding to a request for assistance in addressing some agricultural or food-related problem by researching the issue and duly delivering a solution using nuclear technology which the member state can then implement. The five specialist departments focus on animal health, soil and water management, plant breeding, insect pest control, and food safety and are supported by specialist research laboratories.

Rapidly breeding resistance

Rust, named for the reddish patches on affected plants as well as for the associated pathogenic spores, is a class of serious diseases affecting plants, including cereal crops. Currently an epidemic of wheat stem rust, named Ug99 on account of its discovery in Uganda in 1999, is prevalent in Africa, Asia and the Middle East. It's now approaching Europe and causing considerable concern.

Rust will always reduce yields of infected plants but Ug99 can cause 100% loss and appears to be growing in virulence as it spreads. The implications for wheat harvests and for consequent food security in some of the world's poorest regions are considerable, particularly as rust is difficult to treat. Fungicides can be used but are expensive and have limited success, particularly in humid conditions, hence the only realistic long-term approach is to develop wheat strains resistant to infection.

In May 2009 the FAO/IAEA Joint Division brought together mutation breeding experts from 26 member countries to identify potentially resistant wheat varieties and the genes concerned. However, the problem is immense as ordinarily tens of thousands of individual plants would need to be sown to give a few promising mutations. This is where the technique of mutation induction, using ionising radiation to induce rapid mutation, is bringing very promising results by accelerating the ordinary mutation process so that something which might take many years in the wild can be completed in a fraction of the time.