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USE OF NUCLEAR TECHNIQUES IN FOOD, AGRICULTURE AND PEST CONTROL

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Introduction

The so-called Nuclear Techniques used in agriculture are of two distinct types but both based on the special characteristics of radio-isotopes which give off radiation or on isotopes which are heavier than the normal element.

One type of application uses the radiation given off by isotopes to enable the detection of individual atoms in infinitely small amounts of matter. With this technique we can e.g. follow the travels of fertilizer elements in the soil, into and throughout the crop plant or the travels of animal nutrient atoms throughout the animal and their deposition in milk and meat. This has resulted in enormous advances in crop and livestock research.

Very minute traces of pesticides and their residues can be detected in food, in plants and animals and in the environment enabling the development of measures to reduce harmful effects.

The other type of application makes use of the unique ability of ionizing radiation - x-rays, gamma-rays, electrons and neutrons to penetrate all types of matter and produce changes within living cells. These changes in cells induced by radiation can do three things: (1) can kill the cell; (2) render it incapable of reproducing itself (sterilize); or (3) cause changes in its genetic make-up, called induced mutations.

This is made use of to kill microorganisms in food, prevent sprouting of potatoes and onions, breed better crop plants or sterilize insects for control Some of this can be accomplished by chemicals, but in some cases the chemicals used leave residues dangerous to health or are themselves dangerous to workers because of their mutagenicity or carcinogenity. No chemical can compete with radiation in penetrating packaging material or living tissues, flesh, bones and seeds. Therefore these nuclear techniques have become highly successful tools in both research and processing. Radiation sources on the other hand are normally in self-contained and completely shielded cells with no radiation hazard. Electronic accelerators of course can be turned on and shut off at will like any electronic appliance.

Use of Nuclear Techniques and their Impacts

A. Radiation

There are three main types of uses:

1. To sterilize insects for eradication

2. To induce mutations for plant breeding

3 To kill or sterilize microbes and pests in food and food ingredients to improve quality, shelf-life and wholesomeness.

1. <u>Insect Sterilization</u>

This application is used in the so-called Sterile Insect Technique (SIT). The technique is based on an elegant and simple technique, discovered by the American entomologists Knipling and Bushland: an insect infestation is eradicated by releasing into the infested area sterile insects in a ratio of 10 - 15 times the number of the wild insects found in the area. It should be obvious that if the sterile flies are 10 times as many as the wild flies, the chance of a fertile mating is only 10%. Therefore, the next generation of the wild population is much smaller. If we again release the same number of sterile flies and repeat this over a few generations, we end up with no flies left. As I said, this is an elegant and smart theory but the exciting part is that it works in practice. Using this technique it was possible to totally eradicate the enormously devastating pest, the New World Screw Worm from the USA and Mexico. To do this big factories had to be built capable of producing billions of flies which are all sterilized by gamma rays. You may recall in 1989 when this pest was found in Libya posing a potentially disastrous threat, not only to Libya and North Africa, but possibly to all of Africa, threatening its wildlife, livestock as well as its human population.

Through an emergency programme costing tens of millions of dollars and requiring the transport of 40 million sterile flies per week from a factory in Mexico to Libya. The cases of miasis - the disease caused by the flies - had reached 12,000 in addition to hundreds of cases of human miasis before the release of the sterile flies resulted in the total disappearance of the Screwworm from the continent of Africa.

Another success story concerns the Mediterranean Fruit Fly. The Medfly is undoubtedly the most damaging insect pest of citrus and stone fruits worldwide, resulting in enormous loss in fruit quality and thus of marketable products as well as huge costs for pesticide treatments. The Medfly originated in the Mediterranean area and was first found across the Atlantic some 30 years ago. When it invaded Mexico and threatened its valuable citrus crop, the Mexican Government took immediate steps. With advice from the Joint FAO/IAEA Division and the Seibersdorf laboratory, the Government built a factory in Southern Mexico capable of producing 500 million sterile Medflies per week (about 5 tons). Shortly thereafter systematic releases were started in the infested area with sterilized flies in overwhelming numbers. A few years later the Medfly disappeared from the country of Mexico.

Now there are factories in Guatemala, Chile, Argentina, Peru and Hawaii and it is hoped that the result will be a drastic reduction in the damage caused by this pest in the New World.

Now let us look at the place of origin of the Medfly, here in this area. The damage caused by this fly to fruit production in Egypt and other countries around the

Mediterranean is also enormous. One tries to control the pest by pesticide applications, but there is growing opposition to the use of pesticides due to their secondary effects on wildlife, food supplies and human health. Yet there are no facilities in Mediterranean countries for mass rearing and sterilizing Medflies. Therefore the IAEA together with FAO are advising and assisting Mediterranean countries on the feasibility of using the SIT in this area.

A recent breakthrough in mass rearing the Medfly has made the use of SIT much cheaper, many times more effective and completely harmless to marketable fruit. This breakthrough was achieved in the FAO/IAEA laboratory and enables the killing of all female eggs by simply raising the temperature of the solution containing the eggs by some 10 degrees.

We are working with the Maghreb countries and are running a pilot test in Tunisia. We are also responding to a request for assistance from Portugal for using SIT to eradicate the Medfly from the island of Madeira. At the end of May we held a consultation of plant protection officials from Syria, Lebanon, Jordan, Israel, Gaza and Cyprus in order to consider the technical feasibility of eradicating the Medfly from the whole region, including Egypt. I should add that an Egyptian scientist was invited but was unable to arrive in time.

All these countries suffer from the Medfly and all use pesticides extensively to protect their fruit from the Medfly. The outcome of the consultation was very positive. As a result we are now helping the countries of the region prepare plans for a Middle East regional project for complete eradication of the Medfly betwen Turkey and Libya. The plan is to build a mass rearing factory to be located on Cyprus. It would produce 1 billion flies per week. The flies would be sterilized by gamma rays and released by aircraft, following a carefully prepared plan, in the participating countries. We estimate, if sufficient funds can be found, that the fly could be eradicated from the whole region in 5 - 7 years.

The Medfly cannot survive in low temperatures and does not travel over long distances without suitable hosts. This is why the Medfly will not survive north of Naples or move over the Sahara or east of Amman and Damascus. Thus it would be tempting to eradicate this pest once and for all from all the countries around the Mediterranean. FAO and IAEA are considering the calling of a meeting with technical people from all the countries concerned to look into the feasibility of a Pan-Mediterranean Medfly Eradication Project.

2. Irradiation of Food

Ionizing radiation has the unique ability to penetrate any type of food packaging and the food itself, specifically killing or sterilizing living and active cells in microbes or insects while having minimal effect on the food itself.

Until recently, a variety of chemical fumigants have been used to disinfest fruits and grain or preventing sprouting. Now a number of these fumigants have been found to be harmful, carcinogenic or mutagenic. As a result, many countries have banned nearly all of them, creating great concern in the food industry. Ionizing radiation will effectively disinfest fruits, vegetables and grains without any harmful effect. Even more important is that the products can be packaged, thus preventing reinfestation as long as the package is intact. Now that the GATT accords on sanitary and phytosanitary measures in international trade have taken effect, it is essential that quarantine regulations be met. It is becoming widely recognized that radiation treatment may present not only the most effective means but also the safest way of meeting quarantine regulations and thus facilitate international trade.

It is also becoming widely known that food borne pathogens are on the increase and are causing widespread serious illnesses. WHO says that diarrhea caused by food borne pathogens is the most common cause of child death in the developing world. It is almost impossible to buy chicken in the market which is free of Salmonella or other pathogens. While Salmonella is killed with proper cooking, secondary contamination of e.g. vegetables, continues to cause outbreaks. WHO has recognized that the only effective method of treating chicken for Salmonella is irradiation treatment and indeed recommends to travellers that if possible they should buy irradiated chicken to prevent infection.

The advantages of food irradiation are many and the uses manifold. Yet, it has been difficult to introduce food irradiation into the food industry. There is surprising fear of the use of irradiation in the mind of consumers and consumer unions. For those who know how radiation treatment works and know the results of decades of extensive research into the wholesomeness or irradiated food, it is difficult to understand the basis for this fear. The reason seems to be a general fear of anything "atomic", a belief that irradiated food becomes radioactive - which is never the case - and the association of ionizing radiation with atomic bombs and atomic power plants.

Regardless of the grounds for this unfounded fear, consumers' attitudes must be taken seriously and the consumers and their associations should be given factual information about the true nature of food irradiation and the benefits food irradiation can have for improving and securing food supplies.

3. Mutation Breeding

Ionizing radiation penetrates living plant tissue and can cause changes in the cell nucleus, particularly in the active cells in the seed embryo. These changes affect the chromosomes and the genes and give rise to altered plants. These alterations, called induced mutations, can cause the plant to be shorter, early maturing and more resistant to pests and diseases. The plant breeder selects from the induced mutants those which will improve the performance of the crop.

The results of the application of radiation in plant breeding have been quite dramatic. To date, nearly 1800 varieties of crops and ornamentals of induced mutant origin have been officially named and released to growers throughout the world. Induced mutations have resulted in improvement of practically all important agronomic characters and have resulted in improved varieties in all important crop species, especially in the major cereals. In some countries the induced mutants have come to represent major areas of cultivation, e.g. wheat and rice in China, cotton in Pakistan, rice in the U.S.A., durum wheat in Italy and barley in Europe.

Modern field and horticultural crops are becoming even more refined and higher yielding. In the efforts ahead to double food production in the next 30 years, we are unlikely to find the necessary qualities in existing plant germ plasm collections. The plant breeder will depend on the generation of additional genetic variability which can be induced by mutagenic agents, particularly ionizing radiation. The combination of induced mutations with modern biotechnology and molecular biology has opened up promising new possibilities for crop improvement.

B. Isotopes

1. Soil Fertility

By putting an isotopic label on a fertilizer-nitrogen applied to obtain high crop yields - it is possible to find out how best to apply fertilizers, how deep to place it in the soil, how close to the roots, at what time before or after planting and in what chemical form the fertilizer gives the best results. Many such studies were carried out by FAO and IAEA throughout the world some 20 - 30 years ago. They led to new and improved ways of fertilizer applications. The new methods have long since been incorporated into recommended fertilizer application practices in many countries and for a number of crops, e.g. all the major cereals. Documented savings to farmers and societies as a whole are enormous and may now amount to hundreds of millions of dollars.

Similarly, the use of isotopic tracers in studying the rate of nitrogen fixation by bacteria in symbiotic relation with legumes (peas and beans), it has been possible to develop more efficient ways of employing this symbiotic relationship to replace expensive nitrogen fertilizers. Isotopic techniques are by far the most exact methods of measuring nitrogen fixation rates. The use of isotopic markers in animal nutrition similarly has led to improved animal feeding practices and better utilization of locally available feeds and agricultural wastes.

2. Agrochemicals

There is increasing concern for the impact agricultural practices can have on the environment, especially the harmful effects which may result from careless use of agrochemicals, such as fertilizers and pesticides. An isotopically labelled ingredient in the effective component of such agrochemicals will reveal the presence of the chemical or its residues long after the application as they may appear in plants and animals, water and soil, food or human beings.

For this reason, one attempts with isotopic techniques to assess the impact of various agrochemicals on the environment - on the non-target fauna and flora as well as in food and water.

However, radioisotopes can only be used under experimental and closed-system surroundings since the release of long-lived isotopes emitting harmful radiation is not desirable. therefore most of these applications rely on non-radioactive or stable isotopes which can be identified and traced on the basis of their atomic weight. The IAEA together with FAO and supported by the Swedish International Development Authority is operating three large-scale research programmes to study the effect of pesticides on the fauna and flora in Africa, Central America and in various coastal waters.

3. Disease Diagnosis, Molecular Biology

Isotopic markers are widely used in a variety of basic scientific disciplines which form the basis for much work undertaken in support of food and agriculture. It can be safely stated that without the use of isotopic markers there would be no modern biotechnology, molecular biology and genetics or the myriad spinoffs off these technologies such as modern disease diagnostic techniques. DNA, the basic chemical of life on earth, containing the genetic code, consists of two strands which separate during a phase of reproduction, The basis for molecular biology and genetics lies in being able to identify one strand from the other. This can only be done by a label, in most cases a radioactive isotope (P^{32}).

Work of this nature has led to the many breakthroughs which have occurred in both basic and applied biotechnology. One such application has led to the development of chemicals which are used for the most efficient disease diagnostic method known, called ELISA. This diagnostic method supports a large programme supported by FAO and IAEA in making available diagnostic kits to veterinarians, enabling them to make reliable and quick diagnoses. The large and successful campaign to eradicate Rinderpest from Africa relies on the use of FAO/IAEA supplied ELISA kits. Many other techniques used in the fight against animal diseases rely on isotopic labels: DNA probes, monochlonal antibodies. A related immunoassay technique is based on radiation and is called radioimmunoassay. In FAO/IAEA programmes this technique is primarily used to study the level of the reproductive hormone progesterone. Such studies have given results which have led to shortening of the time interval between calves, thereby increasing markedly both meat and milk production and the grazing pressure on land.

The Role of Nuclear Techniques to Meet Food Production Challenges of the Future

FAO is now preparing a publication showing data and projections for population growth and developments in food and agriculture towards the year 2010 in order to better adjust its programmes to deal with the challenges ahead. FAO is also looking beyond 2010 to discern what really lies ahead in the next centuary. One must remember that e.g. from the time of radiation treatment of a seed to the release of a marketable, improved variety, there may be a 12 - 15 year interval, so that decisions on actions taken today may not be translated into reality until the year 2006 - 2010.

The overriding concern for future developments is the rapid population increase, one million more mouths to feed every 4 days and most of them in food deficient countries.

Another equal concern is for the 800 million souls living with us now on this earth who do not get adequate food and the 200 million children who are undernourished or malnourished and either do not survive or are left with lasting physical deficiencies.

A simple calculation projects that around 2030 there will be 9 billion people on earth, and to feed them all we must double food production.

And this must be done in the face of growing environmental concerns and demands for sustainable development.

Doubling food production would not be so difficult if we would dump ever increasing amounts of fertilizers and pesticides on our crops, have unrestricted access to water and plenty of virgin soils which could be brought under cultivation.

Unfortunately, none of this is available. On the contrary: Soils are eroding at 22 billion tons per year, the earth's soil resources have a half-life of 100 years. Over the last 30 years, cultivated land per person has shrunk some 32%. These trends must be reversed lest our food production capability is not going to deteriorate in the future.

Whatever measures will be taken. one thing is certain: we must rely on science and technology to uncover new methods and new materials, new systems and new crop varieties that will give us a chance. As reviewed above nuclear techniques provide accurate, sensitive, fast and effective tools in research and development. They seem to become more relevant in agricultural research with every year. They are based on some of the most fundamental characteristics of our physical universe, the very nature of atoms and nuclei; it is difficult to imagine technology more firmly based on natural phenomena.

The problems of food and agriculture must be resolved to meet man's most basic and essential needs: the very survival of the individual and the human species. The application of nuclear technology therefore must be problem driven, not simply a demonstration of elegant technology. Nuclear techniques in food and agriculture should not be used aside from and in isolation from the overall effort to increase and secure food supplies. It is for this reason that the International Atomic Energy Agency applies nuclear technology in food and agriculture in a joint programme with the Food and Agriculture Organization of the United Nations. It is an example which should be followed by all national and regional atomic energy authorities.