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Applications of Radioisotopes in Agriculture

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Abstract

Radioisotopes decay by emission of radiation and energy they posses, can be utilized in wide range of agricultural applications. Nuclear scientists and technologist are unlocking the secrets of many agricultural problems, which could not have been possible with conventional methods. Radioisotopes were used for producing high yielding crop seeds to increase the agricultural yield. Radioisotopes were also used for determining the function of fertilizers in different plants. Radiations from certain radioisotopes were also used for killing insects which damage the food grains. Cereals, fruits, vegetables and canned food can be stored for longer periods by gently exposing them to radiations. Applications of Radioisotopes and radiations are helping us to find the solution of problems in much shorter time. The production of radioisotopes by nuclear reactors and other atomic installations have increased the use of radioisotopes in the field of agriculture. India is a leading producer of radioisotopes in the world and our nuclear scientists are engaged in developing various technologies for the beneficial uses of radioisotopes. This article briefly describes the role of radioisotopes and their radiation in the field of agriculture.

Keywords: Radioisotopes; Radiations; Nutrients; Preservation; Sterilization; Tracer technique.

1. Introduction

Nuclear science and technology offers techniques that are being used to improve productivity while conserving valuable resources needed for day to day life (Rao, 1999). Radioisotopes are used as a research tool to develop new strains of agricultural crops that are drought and disease resistant, are of higher quality, have shorter growing time and produce a higher yield. Radioactive elements emit a variety of radiations and energy particles during decay which are used in health care, agriculture and physical sciences for basic research and in wide range of applications (Sahoo & Sahoo, 2006). Radioactive exposure improves quality and productivity of agricultural products along with insect, pest and disease management. They are helpful in study of optimum utilization of fertilizers, insecticides and pesticides in cultivated crops without harmful effects to plants and other living organisms. Radioisotopes have played an important role in improving productivity in agriculture in a sustainable manner. Ionizing radiation is very useful for preservation of agricultural and food products. Many products used in our daily life have in some way benefited from radiation during their production. International Atomic Energy Agency (IAEA) promotes the wider use of radioisotopes and radiation sources in research, industry, agriculture and medicine. Food and Agriculture Organization (FAO) and IAEA works to facilitating development and adoption of nuclear technologies at national and international levels for improving agricultural productivity. The mission of the Joint FAO/IAEA Division is to develop improved technologies for sustainable food security involving nuclear methods. Radioisotopes and controlled radiation are now used in a variety of studies like crop improvement, food preservation, determine groundwater resources, sterilize medical supplies, analyze hormones, X-ray pipelines, control industrial processes and to study environmental pollution. FAO and IAEA jointly supports and co-ordinates research projects throughout the world on the use of isotopes and radiation in the fields of irrigation and crop production, soil fertility, insect and pest control, livestock production, health and food preservation. Improvement of agriculture is one of the most significant contributions that atomic energy can make to meet the challenge of food security for present and future generation, to conserve natural resources and to protect the environment (IAEA, 1996).While some progress in this direction has already been made, the full potential is yet to be explored adequately.

2. Applications in Agriculture

2.1. Plant nutrition studies

Fertilizers are very expensive and their efficient use is of great importance to reduce the production cost of agricultural crops. It is essential that a maximum amount of fertilizer used during cultivation finds its way into the plant and that the minimum is lost. Radioisotopes are very useful in estimating the amount of phosphorus and nitrogen available in the soil. This estimation helps in determining the amount of phosphate and nitrogen fertilizers that should be applied to soil. Fertilizers labelled with radioactive isotopes such as phosphorus-32 and nitrogen-15 have been used to study the uptake, retention and utilization of fertilizers. Excessive use of fertilizers effects biodiversity and damages the environment. These isotopes provide a means to determine about amount of fertilizer taken and lost to the environment by the plant

(Harderson, 1990). Nitrogen-15 also helps in assessment of nitrogen fixed by plants from the atmosphere under field conditions. IAEA develops and transfers techniques that use radioactive isotopes for measuring the nutrient uptake from various fertilizer sources with an aim to achieve higher and more stable grain yields by optimizing the uptake of nutrients from applied fertilizers (Zapata and Hera, 1995). Only small amount of fertilizer applied to the soil is taken up by the crop. The rest either remains in the soil or is lost through several processes. FAO and IAEA have jointly conducted several research programmes for the efficient use of radioactive isotopes for fertilizer management practices in important agricultural crops like wheat, rice and maize (Hera, 1995).

Study of soil characteristics is extremely valuable in devising effective methods of farming. Radioactive isotopes can be used as “tags” to monitor uptake and use of essential nutrients by plants from soil (IAEA, 1996). This technique allows scientists to measure the exact nutrient and water requirements of crop in particular conditions. A major factor in successful crop production is the presence of an adequate water supply. Nuclear moisture density gauges can monitor and determine the moisture content of soil so indicates the exact irrigation needs of a particular area. Nuclear science and technology have greatly facilitated such investigations and are now being widely used in soil plant nutrition research to make the most efficient use of limited water sources. Ionizing radiation is also used to sterilize the soil and there is a good deal of current interest in the use of radiation for the eradication of microorganisms in the soil which causes diseases and are harmful to plant life.

2.2. Insect pest management

Insect pests are responsible for significant reduction in production of agricultural crops throughout the world (Alphey, 2007). Insect pests are serious threat to agricultural productivity. They not only reduce crop yields but also transmit disease to cultivated crops. Radiolabel pesticides were used to monitor the persistence of their residues in food items, soil, ground water and environment. These studies have helped to trace and minimize the side effects of pesticides and insecticides. There are concerns that continuous uses of pesticides have negative impacts on the environment and it also results into development of resistance against pesticides in many insect species (ANBP, 2005). Moreover, pesticides not only kill target species but also many other beneficial pest species responsible for maintaining natural ecological balance in the crop fields.

IAEA is using nuclear science to develop environmentally friendly alternatives for pest control. FAO and IAEA division jointly sponsors projects and conducts research on control of insects using ionizing radiations. They have placed considerable emphasis on the Sterile Insect Technique (SIT) proposed by Knipling in 1955 (Knipling, 1955). This technique relies on application of ionizing radiation as a means to effectively sterilize male insects without affecting their ability to function in the field and successfully mate with wild female insects. This technique involves release of large numbers of sterile male insects of the target species in the field crop. Sterile male insects compete with the regular male population during sexual reproduction and the eggs produced from their mating are infertile so they produce no offspring (Morrison et al., 2010). It is highly specific form of "birth control which reduces and eliminates the insect population after two or three generations. It has been effectively utilized in elimination of Mediterranean fruit fly from US, Mexico and Chile and screw worm infestation in the US and Mexico (Klassen and Curtis, 2005; Wyss, 2000; Lindquist et al., 1992). It has been successfully used to eradicate several insect pests of agricultural significance throughout the world.

2.3. Crop improvement

Plant breeding requires genetic variation of useful traits for crop improvement. Different types of radiation can be used to induce mutations to develop desired mutants line that are resistant to disease, are of higher quality, allow earlier ripening, and produce a higher yield**.** An initial attempt to induce mutations in plants was demonstrated by American Scientist L.J. Stadler in 1930 using X-rays. Later on, gamma and neutron radiation were employed as ionizing radiations. This technique of utilizing radiation energy for inducing mutation in plants has been widely used to obtain desired or improved characters in number of plant varieties. It offers the possibility of inducing desired characters that either cannot be found in nature or have been lost during evolution. A proper selection of mutant varieties can lead to improved quality and productivity.

During last two decades, radiation-induced mutations have increasingly contributed to the improvement of crop plant varieties and it has become an established part of plant breeding methods. Radiation induced mutation experiments are showing promising results for improvement of cultivated crop varieties in many countries. Bhabha Atomic Research Centre (BARC) has developed number of high yielding varieties of tur, green gram, black gram, groundnut, jute and rice by using radiation energy for inducing mutation (Sood et al., 2010). Crop varieties developed by using induced mutations have been found valuable by many national authorities so they have been released and approved for commercial production. Most of the groundnut and black gram grown in India are from mutant varieties developed at BARC. There are many similar successful mutants in use in other countries, for example, high yielding mutant barleys which can utilize higher doses of fertilizer for increased grain production. Improved pearl millet line showing resistance to downy mildew disease was developed using irradiation treatment in India and is now grown over an area of several million hectares.

2.4. Food processing and preservation

Demand for instant food which is wholesome and which has a long shelf life is growing in both the developed and the developing countries. 25-30% of the world’s food produce are lost due to spoilage by microbes and pest and these losses are more in developing countries. This loss of food can be avoided by employing efficient food preservation methods. Radiation can be used to destroy microbes in food and control insect and parasite infestation in harvested food to prevent various kinds of wastage and spoilage. Extension of shelf life of certain foods of a few days by irradiation is enough to save them from spoiling. Irradiation of food has potential to produce safe foods with long shelf life. Certain seeds and canned food can be stored for longer periods by gently exposing them to radiations. Food irradiation is energy-conserving when compared with conventional methods of preserving food to obtain a similar shelf-life (Wilkinson and Gould, 1996). It can alleviate the world's food shortage by reducing post-harvest losses. Food irradiation can replace or drastically reduce the use of food additives and fumigants which are hazardous for consumers as well as workers in food processing industries. Irradiation does not heat the food material so food keeps its freshness in its physical state. The agents which cause spoilage (microbes, insects, etc.) are eliminated by irradiation from packaged food and packaging materials are impermeable to bacteria and insects so recontamination does not take place. Irradiation of food kills insects and parasites, inactivate bacterial spores and moulds, prevent reproduction of microbes and insects, inhibit the sprouting of root crops, delays ripening of fruits and improve technological properties of food. FDA has approved irradiation as a method to inhibit sprouting and to delay ripening in many fresh fruits and vegetables. Several steps were taken by the FAO and IAEA division in close co-operation with the World Health Organization (WHO) to promote international acceptance of irradiated food (WHO, 1988). The Joint FAO/IAEA/WHO Expert Committees on the Wholesomeness of Irradiated Food (1980) have evaluated the safety of irradiated foods for human consumption and concluded that the irradiation of any food up to an average dose of 10 kGy causes no toxicological hazard. Irradiation of food is controversial in many parts of the world (Diehl, 1993). World-wide introduction of food irradiation is necessary to enhance confidence among trading nations that foods irradiated in one country and offered for sale in another, have been subjected to commonly acceptable standards of wholesomeness, hygienic practice, and irradiation treatment control. Efforts and support from international organizations, governments, and the food industry will be needed for the introduction of food irradiation on a truly commercial scale (Diehl, 1990). Some organizations and industries do not recognize this cheap and efficient food preservation method. In the last 30 years of testing of irradiated foods, no harmful effects to animals or humans have been found so now attitude of relevant organizations is changing and some irradiated foods are being released for general consumption. Many countries have accorded clearance for gamma irradiation of food items. The National Monitoring Agency (NMA) of Government of India has cleared radiation processing of onions, spices and frozen sea foods. In India two demonstration plants one at Vashi, Navi Mumbai and another at Lasalgaon, Nashik are providing irradiation service for processing of spices, onions and fruits (Sood et al., 2010).

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