Radiation technology in agriculture

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ABSTRACT

Radiations and radioisotopes are used in agricultural research to induce genetic variability in crop plants to develop improved varieties, to manage insect pests, monitor fate and persistence of pesticides, to study fertilizer use efficiency and plant micronutrient uptake and also to preserve agricultural produce. Use of radiation and radioisotopes in agriculture is one of the most important fields of peaceful applications of atomic energy for societal benefit and BARC has contributed significantly in this area especially in the development of new mutant crop varieties and food irradiation for enhancing food safety, reduce post harvest losses, enhance shelf life and as a quarantine measure for enabling international trade in food and agricultural commodities.

***Keywords*:** Agriculture, atomica energy, mutan crop, radiation, stress

Indian agriculture in the past has witnessed green revolution, which has changed the nation's status from a food importing to a self sufficient nation. In spite of industrialization, India remains an agrarian economy, The national agricultural policy focuses on sustained production and nutritional security for the one billion plus population. By 2025 we may need about 340 million tons of food grains to feed the increasing population (Anonymous, 2014). To increase agricultural productivity equitably in an environmentally sustainable manner in the face of diminishing land and water resources is a highly challenging task. There is a need to develop better crop varieties with better water use efficiency. Which are high yielding and resistant to biotic and abiotic stresses.

Radiation technology in the development of new crop variety

Traditionally, selection and hybridization have been employed in the improvement of crop varieties for enhancing agricultural productivity. Genetic variability in crop plants is a valuable resource from which the plant breeder can select and combine different desired characteristics to produce better crop varieties. Natural variability is generated by spontaneous mutations which occur at extremely low frequency (roughly 10^{-6}). This can be enhanced to several fold (approximately 10^{-3}) using chemical or physical mutagens. Mutations, spontaneous or induced, are an important source for inducing genetic variability. Improvement in either single or few economic traits and quality characters can be achieved with the help of induced mutations within the shortest possible time. Induced mutations have widely been accepted as a supplementary approach in the crop improvement programme, thus speeding up the breeding programme considerably.

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Mutations can be induced using a variety of radiations including gamma- rays (^{60}Co, ^{137}Cs), X-rays, beta particles, neutrons etc. Among these, gamma-rays have been extensively used, due to convenience of handling and better penetrating power. Gamma radiations bring about mutagenesis by interacting with the DNA mainly causing single or double strand breaks. These DNA lesions can lead to simple mutations and chromosomal aberrations. Useful mutations are selected from a large number of random mutations. Among the induced mutants released world wide as varieties for cultivation, about 60% were produced using gamma rays. Some of the other physical mutagens include particle accelerators, electron beams and mutations induced by cosmic rays in space.

Crop improvement programmes at BARC employ radiation based induced mutagenesis along with recombination breeding in oilseeds (groundnut, mustard, soybean and sunflower), pulses (urdbean, mungbean, pigeonpea and cowpea), cereals (rice and wheat), and vegetatively propagated plants like banana and sugarcane. The desirable traits which have been bred through induced mutations include higher yield, improved quality traits, early maturity, disease and pest resistance, improved plant type, increased harvest index, semi-dwarf habit and abiotic stress resistance. Crop improvement programme makes use of the induced variability either by using the desirable mutants directly or by using them in cross-breeding to combine the desirable traits. Induction of modified traits and their incorporation in an ideal genotype could be achieved by a well planned and judicious use of induced mutation and hybridization techniques. 42 new crop varieties developed at BARC have been released and Gazette notified by the moa, GOI for commercial cultivation. These include 21 in oilseeds (15-groundnut, 3-mustard, 2 soybean, 1 sunflower), 19 in pulses (8-mungbean, 5-urdbean, 5-pigeonpea, 1-cowpea) and one each in rice and jute.

Some of the Trombay crop varieties have been very popular among the farming community. These are grown extensively in the country and have made a good impact on our National agriculture scenario by benefiting the farmers considerably (3-5).

Use of radioisotopes in soil sciences and plant nutrition and fate and persistence of pesticides and other agro-chemicals

Radioisotopes are used as a 'tracer' or 'label', which enable scientists to follow the movement of individual atoms and molecules in soil-plant system (D'Souza, 2007). The radioactive atoms reveal their presence by their radioactivity, which can be detected by suitable counters. The experiments using fertilizers labeled with radioactive isotopes facilitate the estimation of the optimum fertilizer requirement of plants, their biological transformations, translocation, the site of utilization in the plant, time of application, and also in quantifying their losses from soil. Radioisotopes are useful in generating information on mineral plant nutrition such as uptake of micronutrients etc using isotopes such as ^{59}Fe, ^{54}Mn, ^{65}Zn, ^{90}Mo etc. The fate of the pesticides and other agro chemicals used in agriculture, their degradation products and their persistence in the ecosystem can also be studied using radioisotopes. For plant uptake and physiological studies, stable isotopes such as ^{15}N and ^{18}O are used as tracer. ^{14}C-labelled pesticides have played an important role in discerning the behavior of these agrochemicals in the environment. Model ecosystems have been developed and used in the laboratory to study the degradation of commonly used pesticides in Indian agriculture. Some of the fertilizers and agrochemicals labeled with a radioisotope such as ^{14}C, ^{35}S, ^{3}H and ^{32}P are tailor made by the Board of Radiation and Isotope Technology (BRIT), Department of Atomic Energy for use.

Insect pest management

Sterile insect technique (SIT) is gaining importance as an ecofriendly approach for the control of insect pests (D'Souza,2007). SIT includes mass rearing of target insect, inducing sexual sterility with radiation in adults (especially males) without affecting their mating vigour and competitiveness and release of such sterile adults in overwhelming number in natural population. This process limits the reproductive ability of natural population and brings down the insect population to a manageable level or even can eradicate completely. At BARC, attempts have been made to study SIT for controlling red palm weevil, potato tuber moth and spotted bollworm of cotton. Pheromones and bio-pesticides have also been developed for use in integrated pest management.

Food irradiation

Merely enhancing food production is not enough. We must ensure its safety, reduce post harvest losses and facilitate fair distribution. The post-harvest losses due to microbial spoilage, insect infestation etc add up to 30 to 50% depending on the commodity. In the next twenty years, an additional 60 to 70 million tons of food-grain will be required annually to feed the increasing population. A significant portion of this requirement can be met by cutting down the post-harvest losses. Over the years BARC has carried out studies on radiation processing of various foods and food-products. It involves controlled application of the energy of radiation such as gamma rays, X-rays and accelerated electrons. This ensures killing of pathogens and storage pests. Radiation processing is also effective in prevention of sprouting in onions and potatoes , delaying ripening and for quarantine measures in fruits. With the establishment of WTO the globalization of trade in food and agricultural commodities has been on the rise. Ensuring quarantine or bio-security in international trade would become mandatory for the exporting countries. The International Plant Protection Convention recognizes radiation processing as a quarantine measure.

We already have two technology demonstration units, one of which is also being commercially used for irradiation of spices and several other food-products. A demonstration plant named KRUSHAK (Krushi Utpadan Sanrakshan Kendra)for using radiation to prevent sprouting in onions and potatoes was commissioned in Lasalgaon Nashik in Maharashtra in 2002. In 2007, this facility became the first cobalt-60 gamma irradiation facility in the world, outside US, to be certified by the United States Department of Agriculture-Animal & Plant Health Inspection Service (USDA-APHIS) for phytosanitary treatment of mangoes. As a result a new chapter in the history of India's agriculture export was written when, on 26th April 2007, the first consignment of irradiated alphonso mangoes left for US after a gap of 18 years. There is a need to extend this processing to other fruits, if India has to realize its potential as the second largest producer of fruits and vegetables. Radiation processing provides an ecofriendly alternative to fumigants which are being banned and phased out due to their deleterious effects on human health and environment. The technology demonstration units set up by the department have generated the much needed 'technology pull' that has resulted in wider deployment of the food irradiation technology for larger societal benefits. A number of entrepreneurs, both in private and co-operative sectors, have plans to set up radiation processing plants for food. Setting up of such gamma irradiation facilities and, in future, the electron beam accelerators will have significant positive impacts on food trade and boost exports of agriculture produce. The wholesomeness, nutritional adequacy and safety of radiation-processed foods was endorsed by world bodies including, WHO, FAO, IAEA and Codex Alimenatrius Commission. In our country, Directorate General of Health Services, has accorded approval for processing of a number of commodities under the Prevention of Food Adulteration Act rules.

Our experience has shown that using radiations for crop improvement has come to stay as an efficient plant breeding method complementing the conventional methods. Clearly, the nuclear technologies have benefited the farmers, traders and end-users and will continue to play a significant role in addressing food and nutritional security.

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