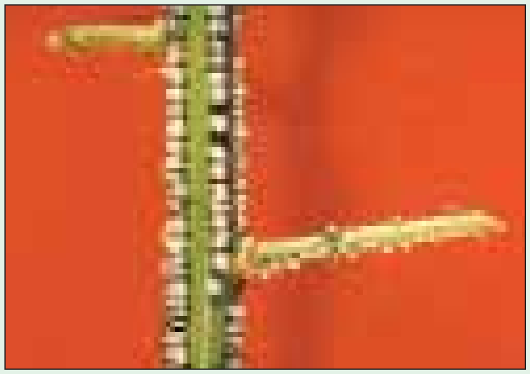
Applications of Radioisotopes and Radiation in Food and Agriculture

Chapter 4

Ensuring Food Security for the Nation

Deployment of radioisotopes and radiation for value addition in food and agriculture sectors is of special significance to India, like any other developing country, where the population is still growing. More food is needed and that too with limlited resources of land and water. Over the last half a century, plant breeders and farmers in India have been looking for ways to improve plant varieties to achieve better crop yields, quantitatively as well as qualitatively. The results have been impressive. Nuclear technology has played its part in helping Indian farmers in their quest for developing new varieties of a number of crops through radiation induced mutation breeding. Today, 25 high yielding and disease resistant varieties of crops such as groundnut, mustard, blackgram and rice are grown in large parts of the country. Radioisotopes have also helped in understanding many aspects of plant physiology – the manner in which plants and crops take up nutrients from the soil, the way the solutes are transported through the plant body, the way biologically important molecules are synthesized by the plant. These studies have led to the development of sustainable agricultural practices, thereby protecting the environment. The post-harvest technology of handling the agriculture produce goes hand-in-hand with increased agricultural output for ensuring availability of nutritious and affordable food to the people. Radiation processing of food to minimize the post-harvest losses is emerging as an important technology for extending the shelf-life of food products.









APPLICATIONS OF RADIOISOTOPES AND RADIATION IN FOOD AND AGRICULTURE
Ensuring Food Security for the Nation

Historical Perspective

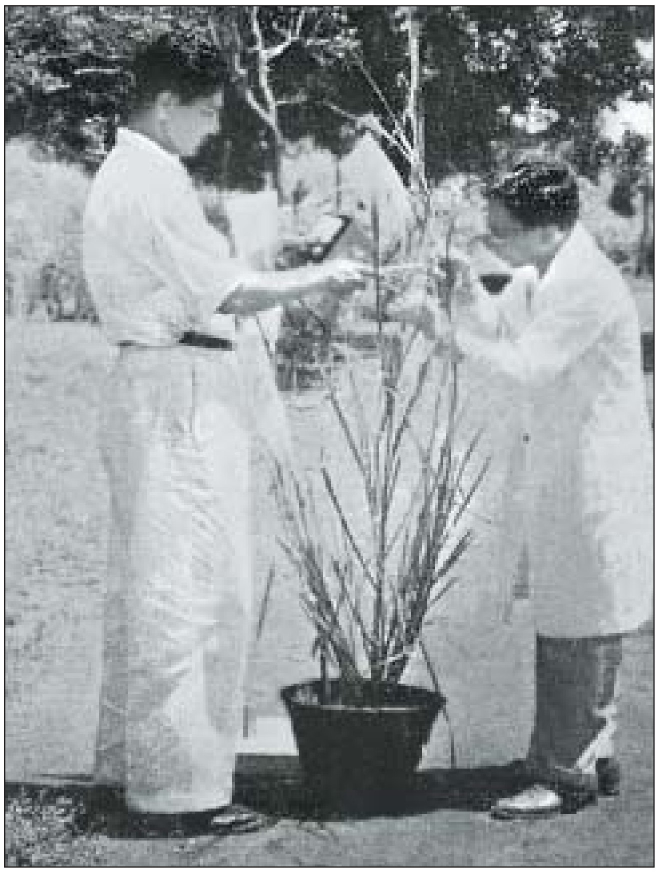
Potential use of radioisotopes and radiations for enhancing agricultural output is of special significance to India, since the Indian economy is still predominantly agriculture based, despite rapid progress in the industrial sector. The conditions were the same, or perhaps even more difficult, at the dawn of independence when the challenge was to increase agricultural productivity to keep pace with the increasing population. Soon after establishment of the Atomic Energy Commission (AEC) in 1948, Dr. Bhabha appointed Dr. Gopal Ayengar to initiate research on radiation biology as there was global interest in studying effects of radiation on biological systems including agricultural crops. In 1953, AEC set up a Biology Division on the premises of the Indian Cancer Research Centre with a mandate to carry out research on the basic aspects of biological effects of radiation and to study biological phenomenon using radiolabeled compounds. Later, with more scientists joining the programme, the laboratories shifted to the Richardson and Cruddas Building in 1960. With the commissioning of Van de Graaf accelerator, CIRUS reactor, and Modular Laboratories at the North site Trombay, the research groups found a permanent location at Trombay and initiated studies on the use of radiation for agricultural applications, food processing as also on effects on other living systems.

Dr. A.R. Gopal Ayengar

One of the areas wherein preliminary work in India was carried out even before independence was related to mutation breeding through exposure of seeds of certain crops like wheat, rice and sorghum to X-rays. However, detailed work on radiation induced mutation breeding was initiated by Dr. Gopal-Ayengar and Dr. K.C.Bora at the then Atomic Energy Establishment, Trombay (now Bhabha Atomic Research Centre). Later, based on the joint proposal of DAE and Ministry of Food and Agriculture, a Nuclear Research Laboratory was set up at the Indian Agriculture Research Institute (IARI), New Delhi, under the auspices of UN Special Fund Programme. With the availability of neutron irradiation facility at APSARA and radioisotopes like cobalt-60, crop improvement programme through mutation breeding was initiated in late 1950s for groundnut. Other crops like mustard, pulses, rice and jute were also included later. Sustained efforts in crop improvement through mutation breeding at BARC have resulted in the development of 25 varieties – ten of groundnut, four of mungbean, four of blackgram, two of pigeonpea, two of mustard and one each of rice, jute and soyabean. These varieties have been released and notified by the Ministry of Agriculture, Government of India, for commercial cultivation. Trombay groundnut varieties are well established in several states such as Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh, Orissa, Rajasthan and Gujarat. A groundnut variety TAG 24 developed at Trombay is the most favourite variety among farmers. Breeder seed indent for Trombay groundnut varieties presently is about 30% of the annual national indent. Among the pulses, blackgram variety TAU-1 has spread all over Maharashtra occupying about 95% of the area under blackgram cultivation. The breeder seed indent for Trombay blackgram varieties is about 40% of the total national indent.

Application of nuclear techniques to agriculture was further enhanced by using radiotracers for optimum use of fertilizer in agricultural practices. Ammonium polyphosphate, a new fertilizer, was developed for rice, pulses and plantation crops. With pesticides becoming an integral part of modern agricultural practices, a rapid increase in the use of organic pesticides was witnessed in the country which aroused environmental concerns. Work was also initiated at BARC to utilize nuclear techniques to study the fate of HCH (Hexachloro Cyclohexane) and DDT in soil samples using ^{14}C-labelled pesticides. Radiations have a direct application in controlling insect pests through sterile insect technique (SIT). Experiments for controlling insect pests such as red palm weevil, potato tuber moth using SIT were also conducted.

A view of the experimental gamma fields at Trombay in early years



Radiotracer experiment (Archive photograph) being conducted to study fertilizer uptake

With the commissioning and operation of CIRUS, the used fuel rods, discharged from the reactor and stored in the water pool, provided a convenient source for initiating work on radiation processing of food products such as onion, potato and mango for determining optimum doses for inhibiting sprouting and delay in ripening. During 1961 and 1965, several interesting research papers were published in these areas in reputed international journals like "Nature" that would be the envy of the best of the biologists today.

Food Irradation Processing Laboratory (FIPLY) at Trombay from early years

In 1967, the food science group led by Prof. A. Sreenivasan moved to the present FIPLY (Food Irradiation Processing Laboratory) building. The building housed India's first pilot plant radiation processing facility, the Food Package Irradiator, a gift from the Atomic Energy of Canada Ltd. It was a token of friendship from Dr. Bhabha's rowing teammate at Cambridge, Dr. W.B. Lewis, who later became the chairman of the Canadian Atomic Energy Programme. FIPLY was one of its kind and the state-of-the-art food laboratory in this part of the world at that time. Unfortunately, Dr. Bhabha could not see one of his dream projects taking shape, as he passed away in a tragic air crash in the Alps in 1966, just before the commissioning of FIPLY. It was for Dr. Vikram Sarabhai to take the reigns as Chairman, AEC and Secretary, DAE, to lead the programme. However, Dr. Sarabhai's efforts were cut short by his untimely death as he passed away in his sleep on December 31, 1971. Dr. H.N. Sethna took over as the Chairman, AEC & Secretary, DAE. A meeting of the Secretaries of the Department of Atomic Energy, Ministry of Health and Department of Food was held on March 3, 1972. The meeting was chaired by Dr. Sethna.

Other participants in this meeting included Dr. Raja Ramanna, at that time Director, Physics Group, BARC, Dr. A.R. Gopal-Ayengar, and Dr. A. Sreenivasan, the two then Emeritus Scientists and Advisors, Dr. G.B. Nadkarni, Head, Biochemistry and Food Technology Division, BARC, K.K. Das, and Dr. J.B. Srivastava, Director General of Health Services, and R.R. Bahl, Secretary, Ministry of Food, among others. A scheme for adoption of new technology was drawn. This included formation of a committee to consider safety measures, if any, required for giving approval for radiation processing of wheat and potato and these studies were to be undertaken by the National Institute of Nutrition (NIN), under the Indian Council of Medical Research (ICMR), in addition to work being done at BARC.

On September 26, 1972 a meeting was held under the chairmanship of the Minister of Health and Family Planning, Uma Shankar Dikshit to discuss matters relating to the processing of food by radiation. The others present were K.C. Pant, Minister of State for Home Affairs, K.K. Das, Dr. P. Dinesh, Additional DGHS, Dr. P.N. Wahi, DG, ICMR, and S.V. Sampat, Joint Secretary, Department of Food. DAE was represented by M.A. Hadi, Joint Secretary, Dr. K. Sundaram, Director, Bio-medical Group, BARC and Dr. G.B. Nadkarni. In this meeting it was decided to refer the whole matter to a Committee of Experts. A Technical Committee was constituted in October 1972 to advise the government on the clearance of radiation processing of wheat, potato, onion and seafood. It comprised Dr. C. Gopalan, Director, NIN, Dr. J.B. Srivastava, DGHS, Dr. K. Sundaram, Dr. A Sreenivasan, from DAE and others from the Department of Food and Indian Council of Agricultural Research (ICAR). The Committee was asked to submit its report for consideration to the Inter-Ministerial meeting in November 1972. However, no meeting took place. Chairman, AEC then requested Ministry of Health and Family Planning for according temporary clearance to wheat and potato in his two letters dated 19.11.1973 and 9.1. 1974. He received a letter dated 25.2.1974 from the Secretary, Ministry of Health, saying that it was not possible to give temporary clearance. At the core of this denial was an adverse report from NIN indicating incidence of polyploidy (higher number of chromosomes) in rats and children fed with irradiated wheat.

Prime Minister Lal Bahadur Shastri being briefed by Dr. Bhabha about Radiation Processeing of Food Programme

An inter-ministerial meeting was finally held on May 1, 1974, in which Minister of Health and Family welfare, Minister for Energy and Chairman, AEC were present. A ‘Scientists Committee’ under the chairmanship of Dr. M.S. Swaminathan was constituted. Dr. C. Gopalan now in the capacity of DG, ICMR, Dr. V. Ramalingaswamy, Director, AIIMS (All India Institute of Medical Sciences), Director, NIN, Dr. S.C. Srikantaiah, and Director, Biomedical Group, BARC, Dr. K. Sundaram were the members. On May 28, 1975, the Scientists’ Committee suggested appointment of a two-member committee comprising Prof. P.V. Sukhatme, an eminent statistician of international repute and Prof. P.C. Kesavan of the Jawaharlal Nehru University, to visit BARC and NIN for evaluating data pertaining to wholesomeness studies conducted by BARC and NIN. Subsequently, the Ministry of Health and Family Planning constituted the Sukhatme-Kesavan Committee.

After detailed discussions and analysis at BARC and NIN the Sukhatme-Kesavan Committee submitted its report to Gyan Prakash, Secretary, Ministry of Health and Family Planning on July 26, 1976. The Sukhatme-Kesavan Committee found no evidence of polyploidy or any adverse changes upon feeding irradiated wheat to rats or children in the NIN data. Subsequently, in September 1976, the NIN data was also reviewed by a FAO/IAEA/WHO Joint Expert Committee on Food Irradiation (JECFI) where Director, NIN was present as an expert member. The Committee was convinced that feeding irradiated wheat did not induce polyploidy, and all toxicological studies carried out on a large number of foods had produced no evidence of any adverse effects. In 1980, JECFI finally concluded that radiation processing of food with an overall average dose of 10 kGy was safe and did not introduce any radiological, microbiological or nutritional problems in food.

In 1987, Dr. Raja Ramanna, then Chairman, AEC and Secretary, DAE, succeeded in setting up of a high-powered committee called National Monitoring Agency chaired by Secretary, Ministry of Health and Family Welfare, to oversee commercial application of radiation processing technology. This initiated the food irradiation programme. By 1991 the Atomic Energy (Control of Irradiation of Food) Rules were drafted and in 1994 the first approval from the Ministry of Health and Family Welfare under the Prevention of Food Adulteration Act Rules was received for onion, potato and spices.

Nuclear Agriculture

Crop Improvement through Radiation Induced Mutations

Basic aspects of development of mutant cultivars

The global biodiversity around us is a result of accumulated spontaneous mutations in the genetic information of all living systems. They are the driving force of evolution. Essentially, mutations arise due to errors caused either in DNA replication that escape proof reading or damage of DNA bases that is not corrected. Plant breeders and farmers depend on genetic variability for crop improvement. Mutations can also be induced artificially. The mutagens include both chemical compounds and physical agents like radiations such as gamma rays and neutrons. Among the radiations, gamma rays are the most preferred as they are relatively easy to access and induce high frequency of mutations. Crop improvement programme utilizes the induced variability either by using the desirable mutant directly or by employing them in the crossbreeding programme to combine the desirable traits.

Mutations

Mutations have been part of the evolution process and arise due to errors caused in DNA replication. Plant breeders and farmers depend upon the mutation technique to develop better crops. Mutation breeding technique is desirable where:

- Natural genetic variability is low
- Undesirable traits need to be removed from the elite variety

Isolating a desired mutant from the progeny of radiation exposed seeds or other parts of plant is the first step. Making the same available to the farmers, as a commercial cultivar requires a lot more efforts and cooperation of many scientists and organizations. After initial evaluation of yield at in-house fields, these mutants are tested at other locations in a series of field experiments under the All India Coordinated Research Trials of ICAR or in trials of the State Agricultural Universities. At the end of three years trials, the performance is evaluated and the new cultivar, if found superior over the best available cultivar, is given to farmers for evaluation on their own fields. A similar procedure with minor modification is followed by each of the states for release in their respective states. This is followed by three stages of seed production namely breeders, foundation and certified seed which is finally sold to the farmers. The overall procedure takes anywhere between 10-12 crop seasons before a new variety reaches the farmers.

Early Successes

Groundnut is a valued crop for edible oil as well as for confectionery purposes. Genetic improvement of groundnut using radiation induced mutation was investigated in detail that resulted in isolating more than 50 morphologically distinct and true breeding mutants. Mutant cultivars developed directly following radiation treatment had limited success in groundnut. The first large pod Trombay Groundnut variety, TG-1 was developed at Trombay following X-irradiation of the seeds of cv Spanish Improved. After evaluation in the all India Coordinated Varietal trials, TG-1 was released in 1973.

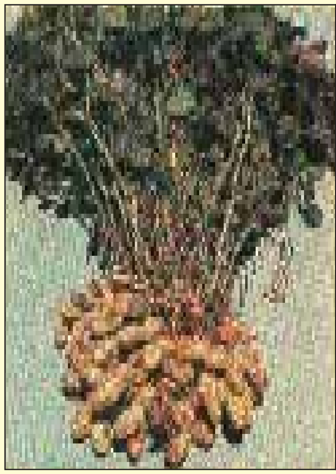
Development of Groundnut Varieties Through Use of Mutants in Cross Breeding

With a view to incorporate the desirable character of large pods,TG-1 was crossed with TG-17, a high yielding mutant variety to transfer large seed character to TG-17. A selection from this cross had the desired size and agronomic traits like seed dormancy. This selection was tested in collaboration with Konkan Krishi Vidyapeeth, Dapoli, Maharashtra and was released as variety TKG-19A for cultivation in the Konkan region. Further, the Spanish bunch type, semi-dwarf early flowering variety TAG-24 was developed after several inter-mutant crosses. This plant has better partitioning of photosynthates leading to high harvest index of 50-55% as against normal harvest index of 30-35%. So far, ten groundnut varieties have been released and some of these have excellent seed qualities required for "Export purpose". The work carried out at BARC has shown that radiation induced mutants can play a very important role in groundnut breeding.

Trombay groundnut varieties

Variety	Year of release	Maturity (Days)	Yield (kg/ha)	Area of release	Salient features
TG-1	1973	130-135	2400-2500	Maharashtra, Gujarat	Large pods, seed dormancy
TG-17	1985	115-120	1400-2000	Maharashtra	High harvest index, seed dormancy,
TG-3	1987	110-115	2000-2500	Kerala, Orissa	More tertiary branches
TGS-1 (Somnath)	1989	110-125	2000	Gujarat	Tolerant to stem rot, large pods
TAG-24	1992	100-105 (kharif) 112-117 (summer)	1300 (kharif) 2500 (summer)	Rajasthan, Maharashtra, West Bengal, Karnataka, Andhra Pradesh, Goa, Orissa	Semi-dwarf, high harvest index, highly water use efficient, responds well to inputs
TG-22	1992	115-120	1677	Bihar	Seed dormancy (50-60 days)
TKG-19A	1994	120-125	2000-2500	Maharashtra	Large pods & kernels, seed dormancy (30 days)
TG-26	1995	110-115	2500	Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh	High harvest index, tolerant to diseases, seed dormancy (20 days) responds well to inputs
TPG-41	2003	115-120	2338	All India	Large seed size (65g/100 seeds), seed dormancy (25 days)
TG-37A	2003	110-114	1993	Rajasthan, Punjab, U.P., Haryana	Early, seed dormancy (15 days), oil content 51%

Trombay Groundnut Varieties

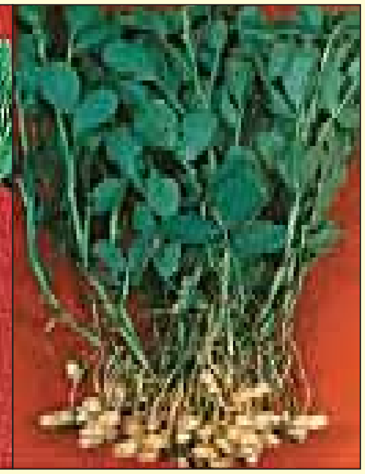


TG-1

TG-3

TG-17

TKG-19A

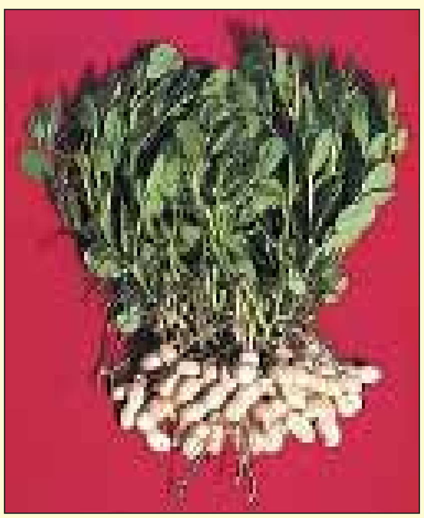


TG-22

TAG-24

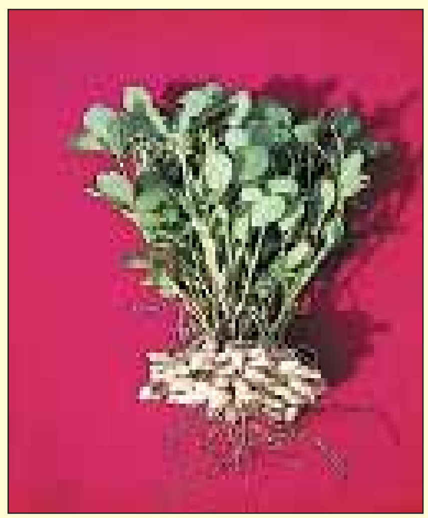
TG-26

Somnath



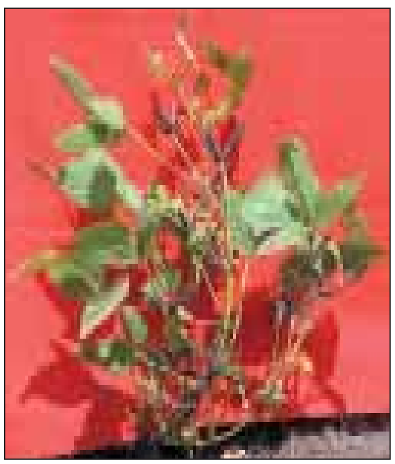
TPG-41

TG-37A



Grain Legume Improvement Programme

Grain legume constitutes one of the main sources of dietary proteins in India. Production of pulses has increased marginally from 11 to 14 million tonnes during the last three decades while the demand is nearly 24 million tonnes in the country. Blackgram is an important pulse crop extensively grown in India. The seeds contain about 22% protein. The area under cultivation in India is about 3.25 million hectares with an annual production of 1.45 million tonnes. About 70% of the total area is in the central and southern parts of the country, which contribute about 77% of the total production. In the past there were attempts at different agricultural research centres to increase production and productivity of this crop using conventional breeding approaches. Classical breeding methods could not make much impact on increasing the productivity of pulses in the country and the yield remained static at around 500 kg/ha. Crop mprovement programme was initiated at BARC during the early seventies in three important legume crops namely, pigeonpea, mungbean and blackgram for induction of mutations for yield, disease and pest resistance. Large number of mutations affecting plant types, maturity, leaf, pod and seed characters were isolated and used in genetic analysis and crop improvement. Eleven high yielding varieties, four of mungbean, four of blackgram, two of pigeonpea and one of soyabean have so far been released for commercial cultivation.



Urad: TAU-1

Mung: TRAM-2

The development, introduction and later popularization of Trombay blackgram varieties in many states have made a significant impact on increasing the production. Blackgram varieties developed at BARC are well suited to central and southern parts of the country. Among those released, TAU-1 with large seed size, has become the most popular variety in Maharashtra, Karnataka and Andhra Pradesh. Presently, TAU-1 is grown in an area of 5,00,000 ha (95% of the total area under blackgram) in Maharashtra state. It was also released in the adjoining state, Karnataka, during 1996. About 20,000 tonnes of certified seed has been distributed since 1990 by Maharashtra State Seed Corporation, Akola to farmers of Maharashtra. The notional income generated due to this increased production amounts to a considerate estimate of US$ 67 million (over Rs. 300 crore) annually. All the other three

Foundation Seed Production of Black Gram Variety TAU-1 (1991-2001)

Year	TAU-1	
	Area (ha)	Production in Quintals
1990-91	3.30	8.65
1991-92	50.40	155.10
1992-93	233.85	1131.00
1993-94	219.04	1186.75
1994-95	378.20	866.87
1995-96	307.45	1186.20
1996-97	698.05	2329.00
1997-98	549.00	999.00
1998-99	547.00	481.00
1999-2000	551.20	1044.00
2000-2001	635.60	1557.00

Certified Seed Production of Black Gram Variety TAU-1 (1991-2000)

Year	TAU-1	
	Area (ha)	Production in Quintals
1990-91	1565.64	3086.86
1991-92	2168.06	16914.45
1992-93	5898.80	26476.00
1993-94	2994.00	13177.00
1994-95	6663.20	11584.01
1995-96	8687.30	29477.70
1996-97	8313.50	29860.00
1997-98	9667.00	29610.00
1998-99	9223.00	13541.00
1999-2000	5781.60	27525.00

varieties TAU-2, TPU-4 and TU94-2 developed under induced mutation approaches are becoming popular in Central and Southern States and the breeder seed indent of Ministry of Agriculture Government of India for all the four varieties was almost 48% of the total indent of blackgram breeder seeds during 2000 – 2001.

Pulse varieties developed at Trombay

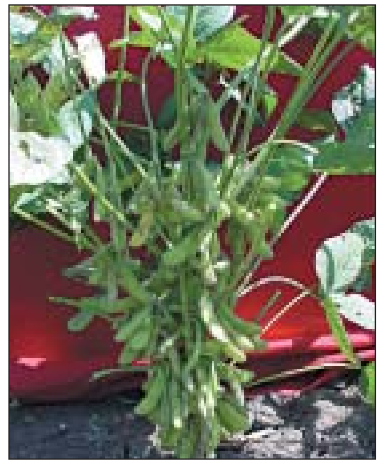
Crop & Variety	Year of release	Maturity (days)	Yield (kg/ha)	Area of release
Mungbean				
TAP-7	1983	60	700-800	Maharashtra, Karnataka
TARM-2	1992	90 (rabi)	1000-1100	Maharashtra
TARM-1	1995	80	765	Maharashtra , Gujarat, Madhya Pradesh, Andhra Pradesh, Karnataka, Kerala, Orissa
TARM-18	1995	65-70	1051	Maharashtra
Blackgram				
TAU-1	1985	70-75	800-1000	Maharashtra, Karnataka
TAU-2	1992	70	900-1000	Maharashtra
TPU-4	1992	70-75	900-1000	Maharashtra, Madhya Pradesh
TU-94-2	1999	70	900-1000	Andhra Pradesh , Karnataka, Kerala, Tamil Nadu
Pigeonpea				
TT-6 (Trombay Vishakha-1)	1983	135-140	1200-1300	Madhya Pradesh, Maharashtra , Gujarat, Andhra Pradesh, Karnataka, Kerala
TAT-10	1985	110-115	900-1000	Maharashtra
Soyabean TAMS-38	2004	95	1800-2200	Maharashtra

Other Crops

In mustard a yellow seeded mutant (TM-1) was induced with radioactive isotope ^{32}P. TM-1 was crossed with Varuna. Two selections from their cross TM-2 and TM-4 were released for cultivation in Assam. From the cultivated rice variety SR 26B, a mutant, TR-5 having about 300 grains per parnicle was isolated. TR-5 was crossed with IR-8 and a high yielding selection TR-21 was developed. This, after extensive testing, was released as Hari in Andhra Pradesh. High fibre yielding Jute variety TKJ-40 was released and is under cultivation as Mahadev in Orissa.

Other crop varieties developed at Trombay

Crop & Variety	Year of release	Maturity (days)	Yield (kg/ha)	Area of release
Mustard				
TM-2(Black seed)	1987	90	1370	Assam
TM-4(Yellow seed)	1987	95	1470	Assam
Rice				
Hari	1988	135-140	6000	Andhra Pradesh
Jute				
TKJ-40(Mahadev)	1983	125-130	2800-3100	Orissa



Soyabean TAMS-38

Some mungbean varieties developed at Trombay

TAP-7

TARM-1

TARM-18

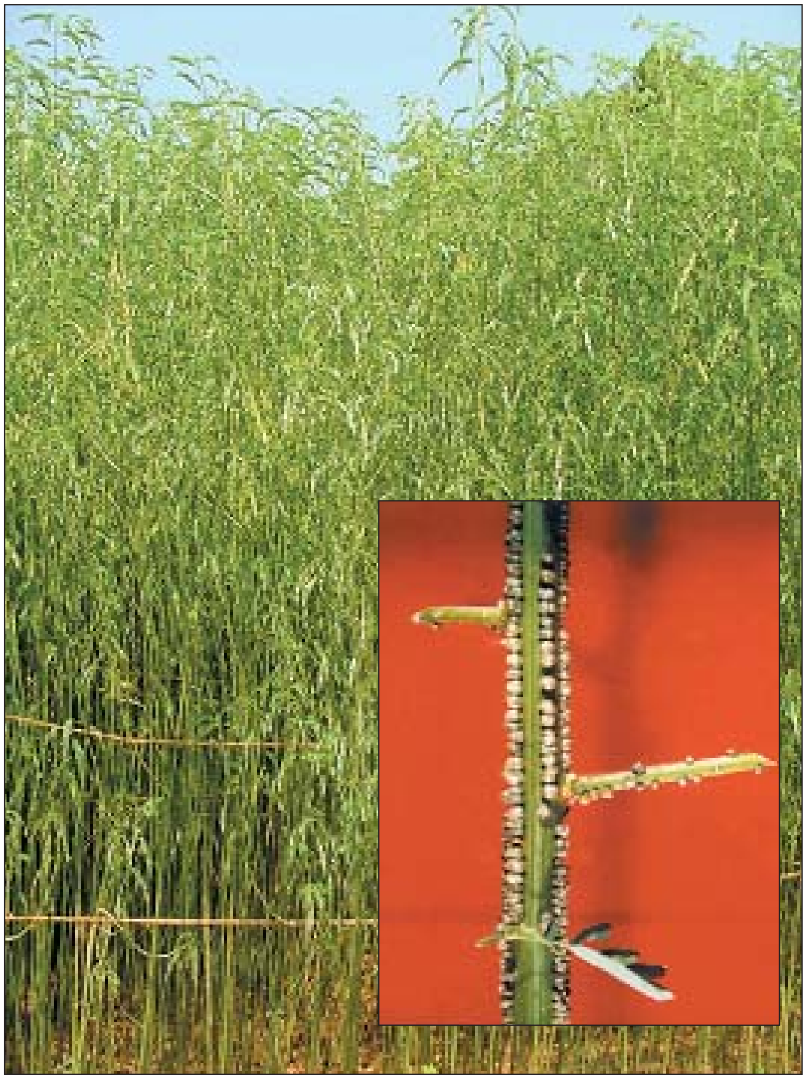
Groundnut variety TAG-24 in farmer's field

Organized Seed Production Programme

The seed production programme of released crop varieties has been initiated by entering into a Memorandum of Understanding (MoU) with the Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra to produce the breeder and foundation seeds. The Maharashtra State Seed Corporation, Akola produces the certified seed and sells it to the farmers.

Sesbania as Green Manure Crop

A radiation induced photoperiod-insensitive mutant, TSR-1 of *Sesbania rostrata* was isolated at BARC. The mutant has higher biomass during short day periods. Samples of TSR-1 have been supplied to several farmers all over the country for multiplication and use as green manure.



TSR-1 : *Photoperiod insensitive green manure plant Sesbania rostrata*

Insect Pest Management

The concept behind the Sterile Insect Technique (SIT) is that a continuous field release of mass produced, radiation sterilized male insects limits reproductive ability of the natural population and this brings down the insect population to a manageable level or even eradicates the menace completely. At BARC, attempts have been made to apply SIT for controlling red palm weevil, potato tuber moth and spotted cotton. bollworm. SIT for controlling the red palm weevil (*Rhynchophorus ferrugineus* Oliv), a serious pest of coconut and other palms, is being tested in collaboration with agricultural universities. The studies on SIT are being carried out for controlling spotted bollworm of cotton (*Earias vittella* Fabricius) under simulated and actual field conditions with sterile males obtained using dose fractionation.

Red Palm Weevil – a damaging pest of coconut being controlled by the use of SIT

Soil Fertility and Plant Nutrition

Radioisotopes are used as a 'tracer' or 'label', which enable scientists to follow the movement of specific molecules in an organism. Radioisotopes are useful in generating information such as efficiency of fertilizer nutrients, quantifying losses from soil and biological transformations of the sample, mineral plant nutrition and allied investigations. Various fertilizers and agro-chemicals labeled with a radioisotope are tailor made and supplied for use.

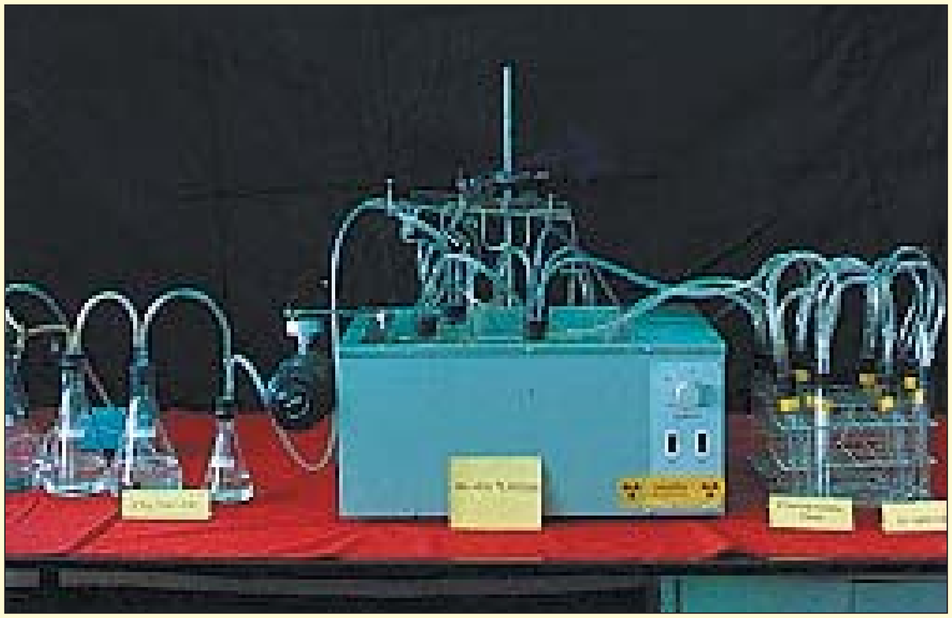
Phosphorous-32 aided studies with several agricultural universities have established that ammonium polyphosphate (APP) provides more nutrients (N+P) per unit weight of the fertilizer and is equal or superior to orthophosphate (DAP) in diverse soil crop regimes. Studies on APP blended with $^{65}ZnSO_4.7H_2O$ as a carrier for zinc indicated that the fertilizer-use efficiency of Zn-APP was significantly higher than that of Zn-DAP for the major crops.

Monitoring of Pesticide Residues

The continuous flow system developed at BARC has helped in obtaining information on mass balance of several ^{14}C-labelled pesticides such as carbofuran, chlorpyrifos, oxyfluorfen, nitrofen, HCH, DDT and endosulfan. Using ^{14}C-HCH and ^{14}C-carbofuran, it was observed that there is no bioaccumulation of these pesticides in catfish. Use of green manure reduces the persistence of ^{14}C-DDT, ^{14}C-HCH, ^{14}C-carbofuran and ^{14}C-nitrofen especially under flooded conditions. A rice-fish ecosystem established in the laboratory showed that carbofuran and nitrofen did not bioaccumulate in rice or fish. In marine ecosystem DDT was found to be degraded in about 60 days while chlorpyrifos was completely degraded in 30 days. There was no bioaccumulation of either pesticide in clams or any other components of the marine ecosystem.

Dissemination of Research Efforts and Popularization of Crop Varieties

For effective extension of these research efforts from laboratory to land and also for production of breeder seeds, effective linkages have been established with Department of Agricultural Cooperation (DAC), ICAR, several State Agricultural Universities, National and State Seeds Corporations, National Research Institutes, State Departments of Agriculture, Krishi Vigyan Kendras and progressive farmers. BARC also participates in Kisan Melas held in farmers' fields as part of the popularization strategy.



Ricefish ecosystem for bioaccumulation studies

Continuous flow system developed at BARC to obtain mass balance of carbon-14 labelled pesticides

Radiation Processing of Food and Agricultural Commodities

The Need for Radiation Processing of Food

Conservation and preservation of food is a prerequisite for food security and it provides economic stability and self-reliance to a nation. The seasonal nature of production, long distances between production and consumption centres and the rising gap between demand and supply have made this even more relevant today. The hot and humid climate of India is quite favorable for growth of numerous insects and microorganisms that destroy stored crops and cause spoilage of food every year. Spoilage can also occur due to chemical and physiological changes in stored foods. Foods in general and sea-foods, meat and poultry in particular, may carry harmful microbes and parasitic organisms that cause illness associated with their consumption.Conservative estimates put post-harvest losses in food and agricultural commodities in India between 20-50 percent, which are worth thousands of crores of rupees. These losses are primarily due to insect infestation, microbiological contamination, and physiological changes due to sprouting, ripening and senescence. Conventionally, post-harvest losses could be prevented by techniques such as cold storage, fumigation, and drying.

Radiation technology can complement and supplement existing technologies to ensure food security and safety. It provides effective alternative to fumigants that are being phased out due to their adverse effects on environment and human health.

The Initial Years

In 1967, India's first pilot plant radiation processing facility, the Food Package Irradiator, a gift from the Atomic Energy of Canada Ltd. was established at FIPLY, Trombay. The irradiator at FIPLY is still the most versatile machine, a work-horse that can process commodities such as onion and potato requiring very low doses (<1 kGy) on the one hand, and spices requiring very high doses (10 kGy) on the other. Besides this, FIPLY also acquired a mobile cesium irradiator with pneumatic controls and a Gamma Cell- 220 for experimental irradiation.

With the commissioning of the Food Package Irradiator possibilities of large-scale experiments and test trials with various commodities had started. A lot of developmental work was carried out with fruits and vegetables, cereals and pulses, and seafood during 1967-1973. Large-scale trials were carried out with the agencies such as Food Corporation of India, and the National Agricultural Marketing Federation (NAFED).

Radiation processing of food

Radiation processing of food involves exposure of food to short wave energy to achieve a specific purpose such as extension of shelf-life, insect disinfestation and elimination of food borne pathogens and parasites. The process utilises energy from ionizing radiation such as gamma rays, electrons and X-rays. Radiation energy is absorbed by molecules of substances like water and other biochemicals that make up food as well as living organisms. Interaction of radiation and radiolytic products of water with DNA impair reproducing capacity of microorganisms and insects as also the ability of potato and onion to sprout. In comparison with heat or chemical treatment, irradiation is considered a more effective and appropriate technology to destroy food borne pathogens. It offers a number of advantages to producers, processors, retailers and consumers. Radiation processing of food has been thoroughly and extensively studied in order to ensure its toxicological, nutritional and microbiological safety. The data available from world-wide research including that from India over the last four decades, were jointly reviewed by experts of the World Health Organisation (WHO), Food and Agriculture Organization (FAO) and IAEA in a series of international meetings. In 1980, FAO/IAEA/WHO Joint Expert Committee on Food Irradiation (JECFI), convened in Geneva concluded that any food irradiated up to a maximum dose of 10 kGy is safe for human consumption. Recently, radiation processing of food with doses higher than 10 kGy has also been approved under the Codex General Standard for Irradiated Food. Independent technical and scientific committees constituted by several countries including India have declared that radiation processed food is safe for human consumption.

The First Successes: Technology demonstration plants

With the first approval for the process coming from the Directorate General of Health Services in 1994, DAE proposed to build a few technology demonstration units, that could be forerunners for commercial plants to be set up by user industry. The first technology demonstration plant was built at Vashi, Navi Mumbai, for medium and high dose applications, primarily microbial decontamination of spices and is operational since January 2000. The source strength was recently upgraded with additional activity of cobalt-60 to 300 kCi. The volume of irradiation, mainly comprising of spices and dehydrated onion, has steadily increased during the past three years and about 3000 tons of materials have been processed so far.

Another technology demonstration unit, KRUSHAK (Krushi Utpadan Sanrakshan Kendra) irradiator at Lasalgaon, district Nashik, Maharashtra, for low dose applications, mainly for sprout control and insect disinfestation of agricultural commodities, became operational in July 2003. The facility is currently loaded with 30 kCi of cobalt-60 . About 300 tons of onion and other agricultural commodities have been processed to date.

Plant for radiation processing of spices located near the spice market at Vashi, Navi Mumbai

KRUSHAK, the technology demonstration plant for radiation processing of onions at Lasalgaon, Maharashtra

Continued Development of Technology

The major thrust of research and development has been on the preservation and hygienization of food and agricultural commodities using ionizing radiation. In the initial years, a lot of work was carried out on primary food commodities such as potato, onion, mango, banana and wheat. Both basic and applied aspects of radiation technology were investigated. Studies were carried out on nutritional, microbiological, functional and organoleptic properties of the processed commodities. Synergistic effects of radiation with other physical methods such as heat and dehydration were also studied. Most of the R&D work carried out in FIPLY has been published in excellent journals devoted to applied and basic research. During the seventies, a number of studies were carried out on testing the wholesomeness and safety of radiation processed foods. These studies included short-term and long-term feeding of processed foods to animals such as mice and rats for testing possible induced mutagenicity. None of these studies revealed any harmful effect of consumption of radiation processed food. Later, these studies helped in obtaining approval for radiation processing of food from the national and international bodies. Today, process parameters for a number of commodities in terms of specifications, optimization of radiation dose, and post-irradiation handling and storage, have been developed. A number of food items were approved for radiation processing under the Prevention of Food Adulteration (PFA) Act Rules in 1994 and 1998. Approval for additional items including seafood for shelf-life extension and pathogen control, disinfestatsion of dried seafood as well as pulses was accorded in 2001.

With the shifting of emphasis to secondary food products, new products and processes, as well as a host of techniques related to quality control, would continue to be developed in-house or in collaboration with other institutes and agricultural universities. Food Technology Division (FTD), BARC, is also working in collaboration with other units of DAE for the development of accelerator based radiation processing facilities and their deployment for commercial use. Several collaborative linkages have been developed under DAE /BRNS sponsored research projects and Memorandum of Understandings (MoUs). At the international level projects have been undertaken under the IAEA-RCA programme.

Road map for wider deployment

Interest in the practical commercial application of the process is emerging for many reasons. High food losses caused by insect infestation, microbial contamination and spoilage, mounting concern over food borne diseases, harmful residues of chemical fumigants and the impact of these chemicals on the environment, the stiff standards of quality and quarantine restrictions in international trade are some of these.

Limited commercial operations have started with the setting up of two technology demonstration units. Wider deployment of this technology on a commercial scale at the national level will need concerted efforts of several agencies of the Government of India. These include Departments of the ministries of Agriculture, Commerce, Civil Supplies and Consumer Affairs, Health and Family Welfare and Food Processing Industries. Besides, the support of R&D institutions dealing with food and agricultural commodities including those under ICAR, CSIR and Agricultural Universities is also needed.

DAE has taken several bold initiatives for wider deployment of nuclear technologies for the benefit of society. For radiation processing of food these include broad-basing regulatory approvals, interface with user ministries and funding agencies for spreading awareness and appreciation of benefits accruing from this technology. Development and deployment of these technologies have been taken up under a national agenda and a steering committee for ‘Nuclear Technology Enabled Development’ has been recently constituted.

Applications of Radiation Processing for Food Preservation

Low dose applications (Less Than 1kGy) Inhibition of sprouting in potato and onion Insect disinfestation in stored grain, pulses and products Destruction of parasites in meat and meat products
Medium dose applications (1-10 kGy) Elimination of spoilage microbes in fresh fruits, meat and poultry Elimination of food pathogens in meat and poultry Hygienization of spices and herbs
High dose applications (above 10 kGy) Sterilization of food for special requirements Shelf-stable foods without refrigeration

Food Items Approved for Radiation Preservation by the Ministry of Health & Family Welfare Under Prevention of Food Adulteration Rules, 1954			
Name of food	**Purpose**	**Dose (kGy)**	
		Min	**Max**
Onion	Sprout inhibition	0.03	0.09
Potato		0.06	0.15
Ginger, garlic		0.03	0.15
Shallot (small onion)		0.03	0.15
Mango	Disinfestation (Quarantine)	0.25	0.75
Rice, semolina (rawa), wheat flour (atta) and maida	Insect disinfestation	0.25	1.00
Raisins, figs and dried dates		0.25	0.75
Pulses		0.25	1.00
Dried sea-foods		0.25	1.00
Meat and meat products including chicken	Shelf-life extension and pathogen control	2.50	4.00
Fresh sea-foods	Shelf-life extension under refrigeration	1.00	3.00
Frozen sea-foods	Pathogen control	4.00	6.00
Spices	Microbial decontamination	6.00	14.00

Broad-based regulatory approvals

For any technology to flourish, the rules and regulations should not be too restrictive. At the same time they should not be lax to undermine safety. Broad-based regulatory approvals harmonized with international regulations such as Codex, could provide competitive edge to radiation processing technology. The Ministry of Agriculture has recently amended the plant protection and quarantine regulations to include radiation processing as a plant quarantine measure in accordance with the International Plant Protection Convention. A petition has been submitted to the Directorate General of Health Services, Ministry of Health, New Delhi, for broad-basing approval of radiation processing on food class/ generic basis as per the harmonized regulations and the Codex General Standard. A meeting of the National Monitoring Agency for this purpose was held in November 2003, after a gap of almost 10 years, which in principle agreed to most of the proposals, and passed it on to an Expert Group for studying these proposals in detail.

Involvement of Other Organisations

Efforts have been made to involve Non-Governmental Organisations (NGOs) and Self-Help Groups (SHGs) for increasing the outreach of the technology to the society. A women's NGO, Annapurna Mahila Mandal, based in Mumbai, started using radiation technology for hygienization of spices and selling the product through their retail outlets in Mumbai and Navi Mumbai. The NGO is currently upgrading its spice grinding facility at Shirwal, near Pune, under a grant from the Technology Information Forecasting and Assessment Council (TIFAC). Another effort has been a MoU between the Hindusthan Agro Co-operative Ltd., a cooperative of the farmers at Rahuri, Ahmadnagar district, and BARC, to use KRUSHAK facility at Lasalgaon, as a business incubator.

Despite proven merit, consumers in general are not familiar with the advantages of radiation processing of conventional food. Consumer research in other countries has shown that with the availability of factual information on radiation processing of food along with the awareness of the risks of food borne diseases, and problems of handling, storage and distribution of food, public opinion has moved in favour of the technology.

Then Prime Minister Atal Bihari Vajpayee being briefed by Dr.Anil Kakodkar, Chairman, AEC about advantages of food irradiation, Also in the picture is B.Bhattacharjee, then Director,BARC

New gamma irradiator being envisaged for food processing in co-operative sector

Summary

Development, introduction and popularisation of Trombay pulse varieties in many states have made significant impact on the availability of large amount of dietary plant proteins for the millions of under-nourished Indian people. Mutation breeding approach followed at BARC through irradiation has been able to break the yield barrier. The induced mutations were used in cross breeding to synthesise an ideal plant type with high yield potential suitable for different agroclimatic conditions. During 2003 seven high yielding pulse varieties developed at BARC were included in the breeder seed production programme of ICAR for different states in the country. The first blackgram variety TAU-1 released during 1985 became the most popular crop variety in Maharashtra and covered an area of 5,000,000 ha (95% area under blackgram). About 2,50,000 quintals of certified seed has been produced and distributed by Maharashtra State Seeds Croporation in Maharashtra, Andhra Pradesh and Karnataka.

Commercial retail sale of irradiated spices

Trombay groundnut varieties are gaining popularity in several states such as Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh and Gujarat. TAG 24 has become the most favourite variety among farmers. This variety recorded over 10 tonnes/ha yield in a field in Kolhapur district, Maharashtra. The variety TG 26 gave the highest yield of 11.4 tonnes/ha in a field in Parbhani district, Maharashtra. Breeder seed indent for Trombay groundnut varieties is about 30% of the total national indent.

Pasteurization was discovered by Louis Pasteur in 1860. There are parallels between the objections made to food irradiation and objections, long since discredited, to milk pasteurization. In fact, in 1906 a milk pasteurization plant in New York city was outlawed. Only in 1920s milk pasteurization became common in the US. Today, we cannot do without this process. Milk pasteurization and chilling plants are common sites even in rural India. The benefits of radiation processing technology could be similar to, if not greater than, pasteurization of milk.