

Nuclear Technique and Agriculture in China

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Nuclear technique is a powerful scientific tool in agricultural research, an area with fruitful achievements in China. Application of nuclear technique in agriculture (Nuclear Agricultural Sciences) based on the development of related science and technology is a high-tech area, and also a significant aspect of non-electrical power application of nuclear technique. As an important component of agricultural science and technology, Nuclear technique application in agricultural field has achieved a lot and made remarkable contributions to the economic, social and ecological development of China. The current paper reviews the achievements, and presents the situation of the application of nuclear technique in the Chinese agriculture briefly. The author strongly suggests that Chinese government should pay more attention to the study on the application of nuclear technique in agriculture, in order to promote its development and contribute more to the Chinese society and agriculture.

Key words nuclear technique application in agriculture (Nuclear Agricultural Sciences), isotopic tracer, radiation mutation genetics and breeding, irradiation processing

Nuclear technique is one of the most important components in modern high technology, and the development and utilization of nuclear energy and nuclear techniques is one of the greatest achievements of modern science and technology. It consists of isotopic technique, nuclear radiation and its probe equipment and facilities. Nuclear science and technology has given the world politics, economy and other areas of science and technology a tremendous influence. Just as pointed out in an International Atomic Energy Agency Bulletin: considering the technical impact, only modern electronics and data processing can be compared with isotopic technique.

1 Nuclear Technique

The research, development and application of nuclear techniques are a comprehensive area of science and technology. Nuclear technique itself focuses on isotopic characteristics, radiation and the effects when radiation interacts with matters. Of course, instrument, equipment and facilities are the key points in its research, development and application. Nuclear technique application together with nuclear power covers almost the entire content of peaceful use of nuclear energy. Nuclear technique application is an important component of nuclear science and technology, and a most active part in the peaceful use of nuclear energy. The application of nuclear technique is comprehensive, highly cross-linking, and merged with other scientific subjects, areas and industries. It is also directly related with the economy and people's daily life. Through its application, agricultural green revolution has been sped up; the improvement of industrial technology has been promoted; environmental protection has been more successful, and human disease control is getting more effective. In one word, people benefit from both social and economic development.

The radiation emitted from radioisotope decay can be used as a sensor to trace the existence of a physical matter and its movement, gather information of material composition analysis and in the industry process monitoring. Another field of its application is to use the physical, chemical and biological effects produced in the interaction of radiation with matters for making new materials, changing material properties and conducting medical treatment. The third area is to use the decay energy of some radioisotopes as an energy source in special location, such as in the polar region, wilderness and space satellites. This kind of energy has special advantages in such a situation.

2 Nuclear Technique in China

The nuclear technique application in China has a

history for more than 40 years. In the middle of the 1950s, nuclear technique application started in agriculture, medical service and some other areas. A development stage was experienced during the 1960s and 1970s. Since the 1980s, nuclear technique application developed very fast in many scientific and industrial areas, especially after the 1990s, it turns to the commercial course, forms a complete system, and the scale and levels gradually rise up. Up to now, more than 300 institutions, enterprises and factories produce isotopes, equipment, facilities and related products. Among them, about 40 institutions including research institutes and educational institutions produce isotopes and label compounds; about 60 enterprises and factories are engaged in the radiation processing, such as production of electric wire, cable, thermal shrinkage materials of cross-linking with radiation; about 140 institutes with more than 2000 scientists and staff are engaged in the application of nuclear technique in agriculture; and around 50 factories are engaged in the research and production of monitoring and measuring equipment and facilities. Isotope and radiation processing becomes an industry with a reasonable scale and level. Its production value reached 16 billions in Chinese RMB. Among this figure, 4 billion comes from the agricultural sector; 3.2 comes from cross-linking with radiation, and other production value of radiation processing is about 5.5 billions; 3 comes from equipment and facility making; Isotope preparation, measurement and monitoring equipment and facility making value 0.4, and ion beam implantation is about 20 annually. In the past decades, scientists and engineers combine research in nuclear techniques tightly with the development of national economy in China, and attention was paid to basic research, methodology and technology. From the scientific and technological point of view, the level of nuclear technique application follows the world development generally. Remarkable achievements have been made, and in certain areas China is taking the lead. Those achievements have evoked worldwide repercussions.

3 Achievements of Nuclear Agricultural Sciences in China

Nuclear Agricultural Sciences is a highly crosslinkage and comprehensive discipline. It is based on nuclear science, mathematics, physics, chemistry, biology and agricultural sciences, and supported by elec-

tronic technology and physical-chemical analysis. It is taking tracer kinetics and radiation biology as its basic theory, and taking isotope, actinometry and radiation protection as its basic methods. Through the use of nuclide tracer, nuclear radiation and nuclear analysis, it apply the techniques to agricultural study and agricultural production. Nuclear Agricultural Sciences has been a key component of modern agricultural science and technology in China. It is composed of the following areas: (1) Soil science, water management and plant nutrition; (2) Food and environment protection; (3) Plant breeding and genetics; (4) Animal production and health; (5) Sterile male insect technique for pest insect control (SIT). Nuclide tracer technique is a meaningful measure for getting biological information, and it is considered as a powerful tool after microscope for biologists. Reviewing the development history of life science in the 20th century, nuclear tracers were engaged in many milestone findings. For example, in 1952, Mr. Hershey and Chase proved that DNA is the genetic information carrier by using ^{35}S and ^{32}P double labeling in a bacteriophage infecting colibaccillus experiment; In 1957, Meselson-Stahl proved the mechanism of DNA semi-conservative replication in colibaccillus by using ^{15}N labeling technique, and genetic information transcription from DNA to mRNA, the finding of Crassulacean acid metabolism (CAM) by $^{14}\text{CO}_2$ tracer technique, variations in the mechanism of CO_2 fixation etc. In those studies mentioned above, the tracer technique acted as a key function. We can say that every development step of modern molecular biology and biotechnology has been supported by nuclear technique directly or indirectly. The achievement of life science sets up a solid base for agriculture sciences and agricultural industry, and of course, nuclear agricultural science is included.

For nearly 50 years of development, Nuclear Agricultural Sciences has become an important component of agricultural science and technology, and a major branch of science and technology to promote agricultural reform, technology innovation and modernization. It has made a lot of significant achievements, which have made remarkable contributions to the development in economy, society and ecology in China. More than 60 achievements got awards at the national level, and 4 of them won the National First Class Innovation Award. Plant breeding by radiation-induced mutations has become a very unique technique in crop genetic improve-

ment, from the amount of varieties bred, areas planted, the benefit achieved and general technical level, China is taking the leading place in plant mutation breeding. Up to the end of 2002, more than 630 varieties in 40 types of plants were bred successfully, accounting for one fourth of the total in the world (2252 varieties). The planting area is 9 million hectares annually, which takes about 10% of the total cultivation with a yield increase of 3.3~4.0 million metric tons.

Tracer technique is widely used in studies of agricultural, environmental and life sciences, and plays an important role in promoting the development of those scientific areas. Through the application of the study results, the acting mechanisms of factors influencing agriculture production were revealed or clarified, and they provide crop planting, soil fertilization, pesticide application and water management in scientific ways. Some results on the relationship between fertilization and plant absorption and utilization, and on the course of crop physiology and biochemistry for improving the cultivation techniques can be directly used in agricultural production, and the yield was increased by 2.0 million metric tones around per year. SIT becomes an important bio-control method of pest insects. Since the 1960's, SIT studies on 10 kinds of insects were carried out. One example is the success of artificial breeding and release of Chinese citrus fly (*Dacus citri*): an orange orchard in Guizhou province has an area of 118 hectares with 100000 orange trees, and the sterile male insects were released continuously. Three years later, because of the population decrease of the orange fly, the damage rate caused by orange fly was decreased from 5.2% to 0.098% and the yield was significantly increased.

Irradiation provides a new method for processing agricultural products and prolonging the shelf-life of food. Irradiation processing could increase farmer's income, raise the value of agricultural products, and improve the quality and safety of food. In agricultural area, irradiation processing values billions of Chinese Yuan yearly.

China has made remarkable achievements in Nuclear Agricultural Sciences, and it is already noticed by the international family. In the 1998 meeting of the Asia and Pacific Regional Cooperation Agreement, the member states recommended China as the leading country in the area of nuclear technique application in agriculture, and later the International Atomic Energy Agency recognized the recommendation.

4 Prospects of Nuclear Technique Application in Agriculture

Nuclear Agricultural Sciences is a component of modern science and high technology, which is a study field on the theory and the application of nuclides, nuclear radiation and related techniques in agriculture and a new cross-linkage scientific area. It is one of the most active research fields in agriculture. The world-wide trend of nuclear technique application in agriculture has appeared: it focuses on the production efficiency and benefits, ecological and food safety using the technique in agricultural production and scientific research widely; combination of nuclear technology, biotechnology and it to promote the yield, quality improvement and the advancement of agricultural science and technology. We should follow the principle of "something should be done, and something should not be done", we should center on the key issues of national economy, science and technology, enhance social development and carry out the basic, applied and development studies in China.

4.1 Nuclide tracer technique has played an important role in the proper use of agricultural resources and ecological-environmental protection

The research results of nuclide tracer in fertilizer, plant absorption of fertilizers, fertilization techniques, the process of crop physiology and biochemistry and cultivation technology improvement have been effective and widely used in agriculture production.

In the future, besides the study areas that have been completed, more attention should be paid to the application and studies of the restore of land contaminated by heavy metals and radioactivity, animal nutrition, hydrogeology, regional agricultural issues (dry agriculture, ecological agriculture, facilitate agriculture, the production of non-grain food crop, soil erosion and control, etc.), and the preparation of new tracer and positive electron emitting tracer. Nuclide tracer technique combined with other related techniques to evaluate, monitor, predict and control ecological environment pollution and soil erosion; to study on the influence affect on sustainable agriculture, control and restore of pollution caused by agrochemicals, radioactive nuclides produced in fission and activation, heavy metals; Nuclide tracer technique combined with related cultivation techniques to raise the efficiency of fertilizer and water, to keep land fertility and productivity, to study on crop cul-

tivation system of high yield, good quality and economic benefit, and the molecular mechanisms of crop breeding and bioengineering, in one word to keep the sustainability of agriculture; to make further use of nuclide tracer technique in the application of animal production, nutrition, reproduction and monitoring and control of animal disease, will be the key points.

4.2 The Role of Mutation Genetics and Breeding in the Green Revolution and Biodiversity Can Not Be Replaced by Any Other Technique

Food security, which means to provide the people enough food, is a strategic target of agriculture in China. Mutation breeding from direct use of mutants to select new variety shifts to pay equal attention to direct and indirect use of mutants in breeding program, and further to create new genes, to increase the genetic diversity of crops, and to raise the efficiency and effectiveness of crop mutation breeding.

Nowadays, the concept of mutation breeding is too narrow and has already been reclaimed as mutation technology. Besides chemical mutation, mutation induced by nuclear radiation, chromosome engineering, genetic engineering, T-DNA inserting, transposition of transposable elements (transposons), the so-called bio-mutation, should be included. Bio-mutation has become an important component of mutation genetics and plant breeding. The combination of mutation technology with biotechnology should be strengthened. The isolation and cloning of favourable mutated genes, which control important agronomic characters, becomes a hot spot, and those mutated genes provide new material for functional genomic research. By using biotech, we can better understand the molecular mechanism of mutagenesis and evaluate the efficiency of mutagens and mutagenizing methods. The results could provide the possibility of predicting variation induced by mutation, and in transgenesis, it may increase the transformation efficiency and widen the variation spectrum by using mutation technology.

Mutation technology can create novel characters that do not exist in natural conditions and/or can't be obtained by other techniques. Currently, the next focus should be grain quality or micronutrients at the context of high yield platform. Mutation technology will surely play an important role in this issue when these germplasm is scarce, especially in bio-fortification and functional foods. Chlorophyll mutation is a common in-

duced character, and also the most important ornamental character. The technique is with a bright future in gardening, and it is widely used in flowers and plants for changing colors. A novel type of green-reversible albino or xanthan leaf color marker have been successfully developed and proved to be of great potential in the production of hybrid crops such as rice, maize, and oil-rape seeds.

4.3 Industrialization of Agricultural Product Processing and Preservation by Using Irradiation is Speeding Up, and the Application of Irradiation Technique is Getting More and More Popular

The development is very fast in agricultural product processing, preservation and sterilization, and also in the industrialization. Now, it is widening and deepening. It is from simple agro-products processing and preservation to multiple purposes, such as to delay the maturity and physiological development, to prolong the shelf-life of the food, to kill insects, to sterile and control microbial, to control quarantine pests, to provide patients with sterile food. In the meantime, studies on the processing technology and technical process of traditional herb medicine and the prepared-traditional medicine should be carried out.

The overall purpose of food irradiation is to improve its quality and especially to ensure food safety. According to the development needs of nuclear agricultural sciences, society and economy, to take high-price agricultural products as the target to study the irradiation processing technology and set up a system of technical standards is the general objective of irradiation processing research. It is the time to pay more attention to the study of seafood and animal meat product irradiation processing.

There are some changes from the administration point of view. Formally, any food processed by irradiation should be approved one by one by the authorities. Now, a tendency is to classify food in category, and the approval of irradiation products is made according to the category. The change made is to simplify the approval procedures and promote the industrialization of food irradiation. Another aspect to promote irradiation processing is the study on the development and utilization of irradiation facility (irradiation source), that is to increase economic benefit of irradiation processing.

With the concern of environment protection, SIT, as a bio-control measure is a practical way to reduce the

amount of pesticide applied for pest control. The research and application should be strengthened in the future.

5 Strengthening the Support to Nuclear Technique Application in Agriculture

Nuclear technique and its application is a competitive developing area in the present world, and Nuclear Agricultural Sciences is one of the most active parts. Food and Agriculture Organization (FAO) and International Atomic Energy Agency (IAEA) of the United Nations have established a FAO/IAEA Joint Division in Vienna, Austria and the division has a budget of U.S.\$ 10 million yearly for the research, technical service and training in Agricultural sector. IAEA has 128 member states, among them about 50 or more have set up institutions engaged in nuclear technique application in agriculture. And in some developed countries, for example: France, Great Britain, the United States and Japan, an industry of nuclear technique application in agriculture as a high technology has been formed, and its developing level has become a milestone. Compared with the situation in those countries, the situation of nuclear technique application in agriculture in China appears hard pressed.

Attention from every aspect was paid to Nuclear Agricultural Sciences during the 50s and 80s, and noticeable achievements were obtained. It contributed a lot to agricultural sciences, agricultural production and agricultural economics in China. The reasons are: (1) specialized personnel education. Leaders and scientists made a lot of efforts to the culture of personnel during the 50s and 60s to meet the needs for the development of nuclear application in agriculture; (2) Nuclear agricultural application got benefits from the basic research of the tracer kinetics, radiation biology and radioactivity measurement and monitoring, and methodologies in tracer, isotope production, radiation protection, and irradiation processing, and other application techniques.

Affected by various factors in the course of social and economic reform, the field of Nuclear Agricultural

Sciences seems unadaptable to the changed circumstances and facing some difficulties. Today, the area of nuclear agricultural application is lying on the achievements accumulated in the past decades. Except irradiation processing, there are not too many projects on radiation mutation breeding, and nuclide tracer research projects almost stop. This situation is caused by both internal and external factors.

The author thinks that promoting the research of Nuclear Agricultural Sciences is meeting the demands of the national economic development; agriculture modernization, the issue of "agriculture, countryside and peasants" needs Nuclear Agricultural Sciences as the technical support, and it is a worthy area to be supported. It is pointed out in a recent (September 20, 2004) IAEA Press Release: "China is home to fully one-fifth of the world's 6 billion-plus people, which it manages to feed on just 7 percent of the world's arable land. It has achieved this by harnessing science and technology and modern soil and water management to maximize use of its relatively scarce resource base for food production. Nuclear science and technology-including mutation breeding, tracer techniques, and food irradiation-continue to play a vital role in these achievements."

The Chinese governmental bodies should strengthen the support to nuclear application in agriculture, including basic theoretical research, methodology of nuclear applying technology and combined tightly with national economic development. Besides supporting nuclear technique itself, the National Natural Science Foundation of China should strengthen the support to the application aspects, and initiate projects on nuclear technique application in agriculture, so as to allow the application to take a position. The Ministry of Science and Technology should make clear which department is responsible for nuclear technique application in agriculture. Only in this way, will Nuclear Agricultural Sciences be full of hope, make further contributions to the national development and "agriculture, countryside and peasants", and create a new period of Nuclear Agricultural Sciences.