Mutation breeding

Mutation, a heritable change in a genetic characteristic of an organism, is a natural process that creates new variants (alleles) of genes. Mutation is the primary source of all genetic variations **existing in any organism**, including plants. Variation so created by mutation provides the raw material for natural selection and is a driving force in evolution.

What is mutation breeding ?

Natural selection operates to bring about evolution of new races and species through the variability created by natural mutations and amplified by subsequent recombination of genes during sexual reproduction. Besides natural mutations that occur spontaneously due to various kinds of radiations and cosmic rays received from the sun and also emitted by several radioactive elements, mutation can also be artificially induced by a number of physical agents like gamma rays and X-rays and several types of chemical agents belonging to few specified groups known as chemical mutagens. The standard technique of creating variability by means of altering genes through induction of mutations by physical or chemical mutagens and using the same effectively through elaborate methods of selection techniques in various generations for improvement of a particular crop species for desired objectives is called mutation breeding. This is frequently practiced by plant breeders all over the world for crop improvement.

Role of mutation breeding in crop improvement

The usefulness of mutation breeding in crop improvement was demonstrated first in Sweden which embarked upon practical plant breeding of agricultural plants by means of X-rays and ultra violet induced mutations. Swedish plant breeders found many chlorophyll mutations in barley by the use of X-rays. They discovered some mutants characterised by dense heads, late maturity and very stiff taller straw. These mutants were found to yield higher and produce more straw than the maternal variety. A very large number of mutations of barley, especially for characters like short stature, stiffness of straw and dense ears was shown to respond in a variety of ways in different genotypes. A variety of barley called ‘Pallas’ developed from stiff strawed and early mutants of the variety ‘Bonus’ was released for commercial cultivation in Sweden. These mutants represented the first actual accomplishments of the production of superior varieties by the use of radiation. Similar useful induced mutants included stem rust resistance in wheat, oat and dwarf mutants in rice. The development of dwarf wheat and rice varieties that led to the green revolution are classic examples of mutation breeding achieved through successful exploitation of the mutant genes—*Norin* in case of wheat and *dee-gee-woo-gen* in rice, which affect a large constellation of characters responsible for their superior agronomic responses.

Induced mutations occur more or less randomly in the genome, even their target cannot be directed. Accordingly, results were more often useful in self-pollinating plant species. Success has also been tremendous in ornamental plants and in vegetatively propagated crops, which usually are heterozygous. Today, mutation breeding for crop improvement is not based only upon classical physical mutagens like X- or gamma rays or classical chemical mutagens such as EMS or NMU, but also upon variation that occurs during *in-vitro* culture and has been termed 'somaclonal variation'. Use of haploids derived from anther culture has found its best application in the 'doubled-haploids-technique', which leads faster to homozygosity for more effective selection.

The impact of induced mutation on crop improvement is reflected in the 3248 mutant varieties officially registered by Food and Agriculture Organisation/International Atomic Energy Agency carrying novel induced variation. Moreover, about three-quarters of these are direct mutant varieties derived from treatment with gamma rays, thus highlighting the importance of peaceful usage of radiations that belong to the group of physical mutagens. All this translates into a tremendous economic impact on world agriculture, poverty alleviation, food security and food production that is currently valued in billions of dollars and millions of cultivated hectares.

Development of crop varieties through mutation breeding

Ever since the epoch making discoveries made by Muller and Stadler 90 years ago, a large amount of genetic variability has been induced by various mutagens, a majority (85 per cent) of them being induced through radiations that have contributed significantly to modern plant breeding. Among the mutant varieties, the majority are food crops.

The cumulative number of officially released mutant varieties belonging to 175 plant species in six continents across the world indicates that Asia tops the regional list with 1965 mutant varieties closely followed by Europe (855) and North America (200). With more than one hundred mutant varieties each, China, Japan, India, Russia, the Netherlands, Germany and USA are the leading countries among approximately eighty countries actively engaged in the development and release of mutant varieties.

During the last five decades, several countries including China, India, Pakistan, Bangladesh, Vietnam, Thailand, Italy, Sweden, USA, Canada and Japan took up extensive crop improvement programmes through the use of induced mutagenesis and mutation breeding and made spectacular accomplishments in evolving several superior mutant varieties in large number of important agricultural crop species including cereals, pulses, oilseeds, vegetables, fruits, fibres and ornamentals. A wide range of characters including yield, maturity, quality and tolerance to biotic and abiotic stresses have been improved in the mutant varieties developed so far.

Although an exact estimate of the total area covered by commercially released mutant cultivars in a large number of countries is not readily available, they are being cultivated in millions of hectares and have made a very significant contribution worth billions of USD in global agriculture leading to solving food and nutritional security problems in many countries of the world.

The most important advantage of mutation breeding is that unlike the genetically engineered transgenic GM products, the end products/varieties developed by mutation breeding do not carry any alien genes. It has no negative environmental impact as well. As such there are no issues detrimental to human health, biosafety and public acceptance etc. Mutation breeding in fact has world wide acceptance.

The Indian contribution to mutation breeding for crop improvement

As one of the top three countries closely following China and Japan and contributing substantially to the number of released mutant varieties in the world, India occupies an important place among the countries actively engaged in crop improvement through induced mutation techniques. Mutation breeding in India has yielded considerable dividends both in enhancing our knowledge on various mutagenesis processes relevant to crop improvement and for developing more than 345 improved mutant varieties belonging to 57 crop species. A close examination of the type of mutagens used and the number of mutant cultivars released in India indicates that largest number of mutant varieties (70 per cent) have been induced by physical mutagens, gamma rays being the most commonly used and also found to be highly successful.

The most up-to-date list of 345 mutant varieties belonging to 57 crop species released in India unambiguously demonstrates the significance and importance of use of mutation breeding in crop improvement in India. The four high yielding chickpea mutant varieties, Pusa-408, Pusa-413, Pusa-417 and Pusa-547 with resistance to *Ascochyta* blight, *Fusarium* wilt and other diseases and pests developed by the author at the Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi and released by the Government of India for commercial cultivation are the first ever examples of direct use of induced micro-mutants in a legume crop in the world. Besides high yield performance under late sown crop, the latest chickpea mutant variety Pusa-547, released in 2006 for cultivation has attractive bold seeds, thin testa and good cooking quality. A major seed production programme of the high yielding chickpea mutant variety Pusa-547 for rapid production of Breeder Seed, Foundation Seed and Certified Seed has been taken up by the State Farms Corporation of India (SFCI) and also National Seed

Corporation (NSC) during the last eight years and more than 30,000 quintals of high quality seeds of the variety Pusa-547 has been produced and distributed to farmers. Similarly several mutant varieties of groundnut—TAG-24 and TG-26, and urdbean (blackgram) variety—TAU-1, released by Bhabha Atomic Research Centre, Mumbai and cultivated in millions of acres in Maharashtra, Gujarat and several other states, have contributed tremendously not only towards achieving the targets of the agricultural production of the respective states, but also to the Indian agricultural economy as a whole.

During the early part of the era of mutation breeding largely through radiations, the technique was used as a tool for improvement of traditional traits like yield, resistance to disease and pest etc., in various agricultural crops. During recent decades, tremendous progress has been made in the research of plant molecular biology and biotechnology, particularly plant genomics. As a result we are witnessing new impulses in plant mutation research for crop improvement, from fundamental studies of mutagenesis to reverse genetics. Breeders are now aware of the newer potentialities and far reaching implications of induced mutation for crop improvement and are able to use it with more sophistication and efficiency than before.

Induced mutagenesis is gaining importance in plant molecular biology as a tool to identify and isolate genes and to study their structure and function. Mutation techniques for crop improvement have also been integrated with other molecular technologies such as molecular marker and high throughput mutation screening techniques. Mutation breeding for crop improvement is entering into a new era: molecular mutation breeding. Therefore, mutation breeding will continue to play a significant role in crop improvement and solving the issues related to world food security in the coming years and decades.