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Mutation Breeding Application and Future Prospects

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Abstract: *Plant breeding is estimated to have begun 9,000 – 11,000 years ago and mutation breeding is simply a new device in the breeder's toolkit. Mutation breeding has been used since the 1930s. It's a means of accelerating the process of developing different traits for selection, such as disease resistance, tolerance to harsh growing conditions, and other valuable agronomic traits. It does not involve gene modification, also known as gene splicing. The objective of this review was to review Mutation breeding. Mutation breeding uses a plant's own genetic resources mimicking the process of spontaneous mutations, that's under way in nature all the time, the basis of evolution. Importantly it broadens biodiversity.*

Keywords: *Mutation breeding, spontaneous mutations, DNA, Induced mutation,Mutagenesis.*

1. Introduction

A mutation is a sudden heritable change in the DNA in a living cell, not caused by genetic segregation or genetic recombination. Mutation breeding is the purposeful application of mutations in plant breeding. Unlike hybridization and selection, mutation breeding has the advantage of improving a defect in an otherwise elite cultivar, without losing its agronomic and quality characteristics. In plant breeding, identify suitable genotypes containing the desired genes among existing varieties is the first step. It would be nothing to consider the application of plant breeding without mutation. Since, in nature, variation occurs mainly as a result of with and without mutations. The application of mutation techniques by using different agents of physical and chemical nature has generated a vast amount of genetic variability and has played a significant role in modern plant breeding and genetic studies. The use of induced mutations over the past five decades has played a major role in the development of smart crop varieties all over the world. The widespread use of induced mutants in plant breeding programme across the globe has led to the official release of 3222 plant mutant varieties from 170 different plant species in more than 60 countries throughout the world (FAO, 2005). The developed varieties increase biodiversity and provide breeding material for conventional plant breeding thus directly contributing to the conservation and use of plant genetic resource.

The concept of induced mutagenesis for crop improvement developed dated back to the beginning of 20th century. During the past 80 years, mutation breeding has been successfully utilised for the improvement of crops as well as to supplement the efforts made using traditional methods of plant breeding (Amin *et al*., 2015). Induced mutation is the ultimate source to alter the genetics of crop plants that may be difficult to bring through cross breeding and other breeding procedures (Khan and Wani, 2004). Mutation breeding is the only straightforward alternative for improving seedless crops. Integration of mutation techniques with molecular approaches is providing exciting opportunities for modern plant breeding. ***Therefore, the objective of this paper is to review mutation breeding application and future prospects.***

2. Literature Review

2.1 Mutation breeding

Mutagenesis is the process whereby sudden heritable changes occur in the genetic information of an organism not caused by genetic segregation or genetic recombination, but induced by chemical, physical or biological agents (Roychowdhur and Tah, 2013). Mutation breeding employs three types of mutagenesis. These are induced mutagenesis, in which mutations occur as a result of irradiation (gamma rays, X-rays, ion beam, etc.) or treatment with chemical mutagens; site-directed mutagenesis, which is the process of creating a mutation at a defined site in a DNA molecule; and insertion mutagenesis, which is due to DNA insertions, either through genetic transformation and insertion of T-DNA or activation of transposable elements (Forster and Shu, 2012). Plant breeding requires genetic variation of useful traits for crop improvements (Novak and Brunner, 1992). However, multiple mutant alleles are the sources of genetic diversity for crop breeding as well as functional analysis of the targeted gene in many cases. The key point in mutation breeding is the process of identifying individuals with a target mutation, which involves two major steps: mutant screening and mutant confirmation (Forster and Shu, 2012). Mutant screening is a process involving selection of individuals from a large mutated population that meet specific selection criteria, e.g. early flowering, disease resistance as compared to the parent. However, these selections are often regarded as putative mutants or false mutants. Mutant confirmation, on the other hand, is the process of reevaluating the putative mutants under a controlled and replicated environment using large samples. Through this process, many putative mutants are revealed to be false mutants. In general, the mutations that are important in crop improvement usually involve single bases and may or may not affect protein synthesis (Mba, 2013).

2.2 Mutation breeding practical consideration

The common practical considerations that need to be taken into account in induction and detection of mutations as summarized as follows (Mba, 2013).

- A perfect understanding of the genetic makeup of the traits to be improved is very important.
- Understanding the mode of reproduction of the target crop is also a prerequisite, whether asexually or sexually propagated. If it is asexually propagated, then the method to employ is the next question: whether it will be in vitro or in vivo. If the crop is seed propagated, the question will be on the type of fertilization (self or cross-fertilization) to be used.
- The determination of the material that is to be used for the propagation prior to treatment, i.e. gametes or seeds for sexually propagated crops; and stem cuttings, buds, nodal segments or twigs for asexually propagated ones.
- Knowledge of the number of sets of chromosomes in the nucleus of a cell (ploidy) of the target crop, especially when it relates to how hybridization barriers could impact on the predicted effectiveness of the induced mutants.
- Determinations of the genetic pedigree of the target crop for inducing mutations, i.e. selecting homozygous plants and the best genotype that is deficient in a single trait.
- Selection of an appropriate mutagen (physical or chemical mutagens) and dose (duration and concentration of mutagens). That is why a pilot assay is advisable to be carried out prior to the large-scale treatment of propagules.
- Identification of infrastructure (irradiation house, laboratories, screen/glass house, fields, etc.) for successful selection of desired mutants.
- Screening techniques for dissociation of chimeras from stable mutants.

2.3 Strategies of mutation breeding

Any mutation breeding strategy requires several sequential steps. The effectiveness of mutation breeding over other breeding methods depends upon the efficacy of selection of useful variant mutants in the second (M2) or third (M3) generation. The first step in mutation breeding is to reduce the number of potential variants among the mutagenized seeds or other propagules of the first (M1) plant generation to a significant level to allow close evaluation and analysis (Roychowdhury and Tah, 2013). Determination of the target population size in the first generation of mutants is a prerequisite for potential success in any mutation breeding programme. The targeted population should be fixed so as to allow a high number of mutation measurements. Thus, the population size should be managed effectively by the breeder. It should be noted that the population size depends on the inheritance pattern of the target gene.

Therefore, it is advisable to select mutagens that give a high mutation frequency so as to reduce the population size of the M1 generation (Roychowdhury and Tah, 2013). Genetically, Ml mutant plants are heterozygous. This is because only one allele is affected by one mutation during treatment. However, the probability of having a mutation on both the alleles concurrently is a product of individual probability of mutation. Therefore, its occurrence is extremely low. Moreover, in Ml, only dominant mutations can be identified, while it is impossible to identify a recessive mutation expression at this stage. In this case, a plant breeder should attempt screening mutations in subsequent generations where segregation will occur (Roychowdhury and Tah, 2013). Consequently, the plant breeder generates homozygotes for dominant or recessive alleles. Caution should be taken to prevent cross pollination among the M1 population as this would lead to generation of new variation which will be difficult to differentiate from the effect of mutation (Roychowdhury, 2011). Screening and selection start in the M2 generation.

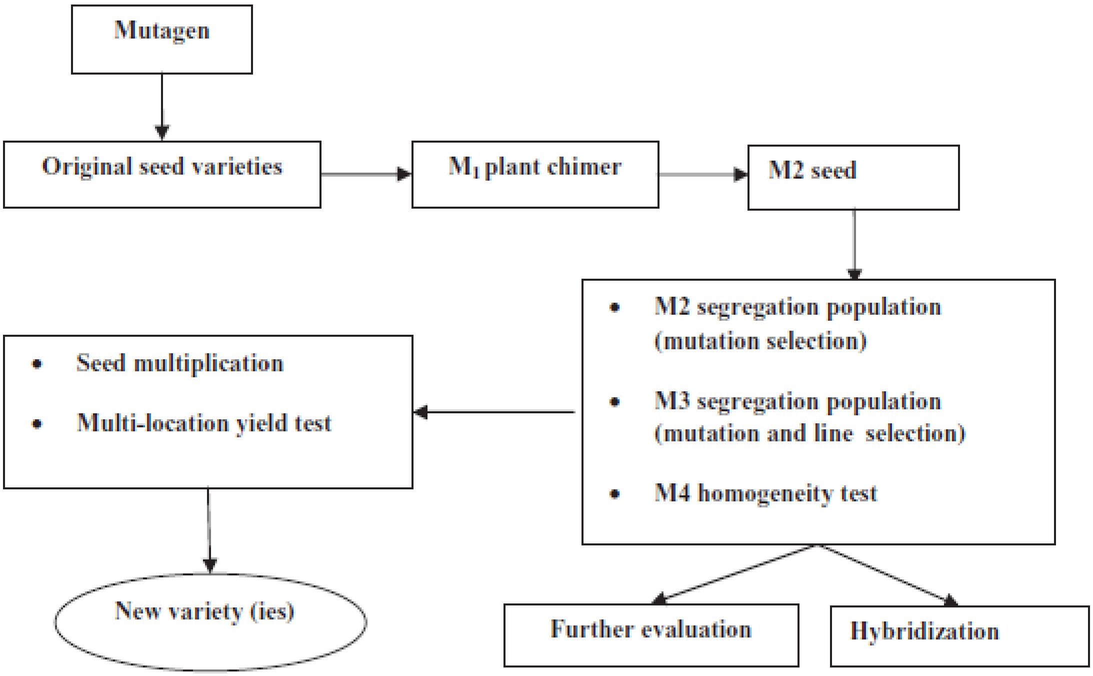

Figure1. *Methods of mutation breeding (Yusuff et al., 2016)*

2.4 Applications of mutagenesis in basic research

The gigantic advent of induced mutation breeding is anticipated to promise a sound solution to further increase food production by both increasing grain production and stability. The application of mutation techniques has generated a vast amount of genetic variability and is playing a significant role in plant breeding and genetics and advanced genomics studies. Recently mutation breeding techniques have also been integrated with other molecular technologies such as molecular marker techniques or high throughput mutation screening techniques are becoming more powerful and effective in breeding crop varieties. Mutation breeding is entering into a new era; molecular mutation breeding. Therefore induced mutation breeding will continue to play a significant role in improving world food security in the coming years and decades. The widespread use of mutation techniques in plant breeding programmes throughout the world has generated thousands of novel crop varieties in hundreds of crop species, and billions of dollars in additional revenue (FAO, 2005). The wide spread use of induced mutations in plant breeding programs has led to the release of elite mutant plant varieties. Such mutants play a significant role in designing crops with improved yield and yield contributing traits, quality and longer shelf life, enhanced stress tolerance and reduced agronomic inputs.

2.5 Future prospects of mutation breeding

Mutation in association with the new technology of genetic engineering will constitute tools of plant breeders in near future. Although most of the varieties released so far has been developed from a mutation in combination with the direct selection. A coordination of the recent techniques of anther and microspore culture, cell suspension, irradiation of haploid cells and chromosome doubling and regeneration of doubled haploid plants could be utilized to obtain genotypes with desired traits (Szarejko *et al.*, 1995). The induced mutation has also proved useful in the preparation of genetic maps that will facilitate molecular marker assisted plant breeding in future (Schwarzacher, 1994). Mutation breeding has become increasingly popular in recent times as an effective tool for crop improvement (Basu *et al*., 2008). The direct use of mutation in the development of molecular maps in structural and functional genomics could lead to rapid improvement of plant yield and quality.

3. Conclusion

Currently, genetic variability is narrowed using conventional breeding approaches for a long period, induced mutagenesis are one of the most important approaches for broadening the genetic variation and diversity in crops to circumvent the bottleneck conditions. Mutation and its breeding strategies are potential tools for improving both quantitative and qualitative traits in crops within a much shorter period of time than conventional breeding. Because of its relative simplicity and low cost, mutagenic treatment of seeds and other parts of the plant remains a useful tool for isolating the desired variants and developing resistance to biotic and abiotic stresses in various crops. Crop varieties generated through the exploitations of mutation breeding are significantly contributing to global food and nutritional security and improved livelihoods.

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