The Impact and Future Prospects of Mutation Breeding in Indian Agriculture

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Abstract**—** *The scientific breeding method that creates mutations, mutation breeding, revolutionizes agriculture by cultivating a higher yield of the crop and making them more resilient. Challenges such as mutation unpredictability and ethical aspects exist. Nevertheless, mutation breeding should be considered as a sustainable practice of agriculture that ensures climate adaptation and food security. Coordinating technological developments, suiting it with other methods of breeding and dealing with socio-economic challenges are essential in this regard for the future of gene editing in the different agro-climatic regions of India.*

Keywords— Mutation breeding, Agriculture, India, Sustainability.

I. INTRODUCTION

Mutagenesis or mutational breeding, which is a scientific method, has tremendously changed many aspects of agriculture. The technique involves the deliberate induction of mutations in the genetic information of an organism, thus creating a wide array of variants that can be selectively utilized to improve crops. The functions of mutation breeding in agronomy are multifaceted but significant which had lead to the increasing crop productivity. The world's population is getting bigger and thus the demand for food is growing as well. To meet the higher consumer demand, it is thus essential to enhance crop varieties that yield more, irrespective of the favourable conditions. Mutation breeding has been able, therefore, to overcome this problem, and has played a key part, along with other methods, in the development of high-yielding crop varieties (Ahloowalia *et al*., 2004). Particularly, mutation breeding is one of the indispensable means to increase the nutritional value of crops. It has been possible to achieve enhanced nutritional qualities in crop varieties through the use of induced mutation. Likewise, a variety of rice with higher protein content as well as maize with increased essential amino acid level has been developed. This aspect is especially true in areas where malnutrition is the norm that the improved varieties of crops can also bring about better health outcomes. (Shu *et al.,* 2012). The other important issue of mutation breeding is that it can be used to create cultivars resistant to pests and diseases. It not only limits the dependency on the synthetic pesticides, hence lowering the risk on the environment and agriculture, but also helps in the sustainability of crop production. Breeding pest and disease resistant crop varieties can virtually eliminate or dramatically reduce crop losses, thus maintaining food security and supply (Jankowicz-Cieslak *et al.,*2017).The emergence of mutation breeding as the crucial means for generating climate resilient crops is a response to the threats of climate change. It is used, in the development of varieties, which are tolerant to different types of abiotic stresses for instance, drought, salinity and extreme temperatures. Hence, this is particularly important for regions like India, where agriculture is a key economic sector but remains sensitive to climate change impacts. The development of climate-resistant crop varieties will make sure that farming remains sustainable in the face of so many challenges (Parry & Hawkesford, 2010). On the other hand, it needs to be pointed out that mutation breeding also comes with several difficulties. Altering the genetic material by means of inducing mutations is random and unpredictable, and not all induced mutation results in beneficial traits. On the other hand, there also exists a set of ethical issues related to the alteration of hereditary material. Hence, a detailed research must be conducted to observe ethical standards whenever this technique is use,mutation breeding potently resonates on the scene of contemporary agriculture. It provides a multi-purpose tool to combat these problems such as food security,

malnutrition and climate change. Nevertheless, this technology needs to be approached with caution owing to its problems that it poses.

II. HISTORY OF MUTATION BREEDING

Mutation breeding is a method that involves the intentional creation of mutations through induction, with the purpose of introducing variations in the plant species. This has been one of the main elements driving agricultural development in India. This technique, which edits an organism's DNA to produce a permanent mutation, has been a vital factor in the breeding process and in enhancing crop varieties during the early 20th century. Varies de Vries, a Dutch botanist, was the first one who brought the theory of mutation in the early 20th century. De Vries, without selecting for any particular trait, recorded mutations that occur in the evening primrose and posited that new species may emerge suddenly in this manner. This pivotal discovery has become the foundation for the innovation of mutation breeding. Within the 1930s and 1940s, the experts discovered that they could set the mutations using irradiation and chemicals. This resulted in the rise of accelerated breeding using mutations as an alternative for developing crops. This was seen as a novel strategy of increasing yields and disease resistance (Larkin & Scofcroft, 1981). In India the first varieties of crop which were evolved through mutagenesis were released in the 50s and early 60s. To start with, the varieties of peanuts, barley, and rice that were resistant to diseases, or had increased yield, were also introduced. The successes of some of these early attempts identified the potential of mutation breeding as an improvement tool for agriculture. Form the 1970s; mutation breeding has been exploited to establish different varieties of many crops. In India, rice, pulses, and oilseeds are species that have benefited greatly from hybrid breeding. This technology has been used to increase the production, biofortification (nutritional value) and disease resistance in these crops, and thus has helped immensely in ensuring food security in the country (IAEA, 2000).

Bhabha Atomic Research Centre (BARC) is the leading institute that conducts mutation breeding in India. They have built new varieties of crops such as groundnut, mustard and chickpea that help to produce more and have resistance to diseases. The intensity of these varieties has been extensively accepted by farmers hence, increasing the agricultural productivity (BARC, 2000). Alongside BARC, other research centres such as IARI and agricultural universities in different states of the country have also made notable contributions to mutation breeding in India. These institutions have implemented a multitude of research projects on the mutation breeding and have bred numerous mutant crop varieties. Although the approach has gained some traction, it is also limited or, perhaps, risky. These are the cases of the evil nature of mutations and the challenge in controlling the mutation process. So, it is significant to take this approach in a responsible way and together with other methods of breeding. It is imperative for the scientists to do more and more research and development to eliminate flaws of this technique and control its adverse consequences (Larkin & Scowcroft, 1981).

III. TECHNIQUES IN MUTATION BREEDING

Mutation breeding, known alternatively as induced mutation, is a scientific process that entails the intentional induction of mutations to give rise to modifications in plant species. This technique was highly instrumental in crop varieties improvement and in enhancing productivity hence, agricultural development in India. The mutation-breeding process consists of several stages. The first stage consists in mutation induction, which can be done by the physical mutagens (e.g. radiation) or chemical mutagens (e.g. EMS). The type of mutagens determines the choice of mutagen and the species of plant which is the key factor. For example, radiation is a common technique of applying large-scale chromosomal variations, while chemical mutagens are a technique used for inducing point mutations (Shu *et al.,* 2012).After the induction of mutations, the mutated plants are cultivated on the field and the same are selected on the basis of favourable characteristics. This process is referred as phenotypic screening which involves watching out the plants for varieties of changes in their characteristics such as yield, resistance against diseases or nutritional content. This step is the most crucial one since it allows breeders to select the most favoured mutant plants which will later be subjected to the next round of breeding. Having a plant with the traits you want is the first step for producing seeds of this plant which will be able to produce stable lines of plants with the same traits. Likewise, there is a process called backcrossing in which the mutant plants are crossed with the parents so as to keep the desirable traits stable and transferred to the next generation. The development of the trait is the last but not the least important step for the market introduction of the mutant varieties (Bado *et al.,* 2015).

India has seen good progress in mutation breeding in terms of improving the varieties of rice, pulses and oilseeds. The technology has helped to increase the yield, nutritive value and resistance to diseases of these crops, and thus, the country can now achieve food security. The Bhabha Atomic Research Centre (BARC) is one of the top research institutes in India that have contributed to mutation breeding research through their human resource development, technical know-how, and genetic stock importation program. A number of these crops have been made into multifarious varieties, e.g. groundnut, mustard, and

chickpea, which are high in yield, and resistant to diseases. These hybrid varieties are widely adopted by farmers; they have resulted in the increase in agricultural productivity. However, mutation breeding is not faultless since it has limits also. These include the fact that the process of mutation desirability of the mutation process itself and the difficultly of controlling the mutations. Due to this, we should be careful about the use of this kind of technology and it should be combined with other breeding methods. The necessity for continuous research and development is crucial to improve the technique and to reduce its potential risks (Larkin & Scowcroft,1981).

IV. CASE STUDY: THE IMPACT OF MUTATION BREEDING

Mutation breeding, or induced mutation, is a very popular method applied in the agricultural science as a very means of improving plants of a particular species. This technology has played the very decisive role in the enhancing crop yields and in the developing cultivars especially in India. The process involves inserting mutations in the plant's genetic material to create the variations that can increase the crop yield, also boost disease resistance or increase nutrient content. The first phase of the mutation breeding is the creation of the mutations. It is often accomplished using mutagens, the physical ones like radiation and also chemical ones like ethyl methanesulfonate (EMS). The choice of mutagen is determined by the type of mutation for which the best options and also the species of the plant. Such as, the large-scale chromosomal changes are mostly induced by the radiation, while chemical mutagens for the point mutation (Shu *et al.*,2012). The mutated plants are then grown and the desirable characteristics are identified after many mutations have been introduced. This process is known as the phenotypic screening which is a set of the observations of the plants for any changes in characteristics like yields, disease resistance, and also nutritional content. This step is a pivotal point where the backcrossing and also other methods are used to choose the best of the mutant plants (Bado *et al.*,2015). The next stage is to select a plant that has the desired characteristics. Then, breeding is done to produce the lines of plants that have the same traits. This procedure is named as backcrossing and it involves the crossing of the mutated plant with its parent to make the desirable traits stable and to be able to pass them on to the future generations. The introduction of these mutant varieties is thus a prerequisite to a more extensive commercialization of the many varieties. (Bado *et al.*, 2015).

In India, mutation breeding has thus far had greater success in improving variants of rice, pulses and oilseed crops. This technique has been applied to improve crops yield, nutritive content, and disease resistance and hence the country food security is influenced in a great way. Bhabha Atomic Research Centre (BARC) is one of the major stakes in mutation research in India. They have transgenic ones too, such as Bt groundnut, Bt mustard, and Bt chickpea, which have high yield and disease-tolerance characteristics. These varieties were widely accepted by farmers causing increase in agricultural yield. Likewise, mutation is also limited. There are two prime defects associated with this method which include bringing in harmful mutations in the body and the difficulty in controlling mutations process. Hence, this approach has to be handled appropriately and with other breeding strategies. It will be important to continue research and development in order to further improve and minimize the risks involved (Larkin and Scowcroft, 1981). The application of mutation breeding has resulted in a considerable rise in agricultural productivity in India, leading to the construction of varieties resistant to yield and diseases. The interactive case study will deal with the question of mutation breeding in India, showing the application in rice, pulses and oilseeds, as well as the organizations which participate in this project.

The BARC (Bhabha Atomic Research Centre) has been a pioneering institute in the arena of mutation breeding research in India. Many types of these crops have been developed containing genes of the various wild species which are resistant to disease and capable of producing good yield. This type of crop varieties is widely accepted by farmers which resulted in an increased agricultural productivity (Bhabha Atomic Research Centre, 2018). One of the most well known cases of mutant breeding in India is by BARC where the Trombay groundnut, a variant of groundnut, was developed. Unlike the other types, this variety is rich in oil, has high yield, and is resilient to diseases (like leaf spot). The Trombay Groundnut is widely adopted by farmers in many states and which also helped increasing oilseed production in India (Bhabha Atomic Research Centre, 2018).Mutation breeding has also been applied to create more improved varieties of rice in India. 'Trombay Basmati' is a mutant variety that was developed by BARC and is known to be of more yield and quality when cooked than the traditional basmati rice. This strand, which has been embraced by farmers in many states, has contributed to higher production and exports as well (Bhabha Atomic Research Centre, 2018). Besides all its achievements, mutation breeding also has disadvantages. These include the fact that they might produce dangerous mutations and the troubles associated with monitoring mutation processes. Therefore it is highly important to apply this technique in a responsible way, combined with other breeding techniques. The pursuit of perfection through constant research and development may eventually enable to remedy the possible effects (Larkin and Scowcroft, 1981). Despite some concerns which exist, mutation breeding has undoubtedly made a noticeable contribution to agriculture in India by introducing high yielding and disease resistant crops varieties. Institution like

BARC has contributed to this research greatly, creating types of crops mutant that have been dominated for decades by farmers all over the world.

V. CHALLENGES AND LIMITATIONS OF MUTATION BREEDING

This method has been employed in India to develop improved varieties of crops such as rice, wheat, and pulses. However, there are several challenges and limitations associated with mutation breeding.

Firstly, the disagreement and randomness of mutations are a challenge. Mutations can occur in regulatory regions, protein-coding regions, and often, they are detrimental. In that way, the random nature of mutations makes it hard to obtain the highly preferred trait and thus the large number of plants has to be screened to find good mutation. (Bhatia *et al.*,2016).

One of the major problems associated with mutation breeding is that it is a time and resource consuming technology. Stabilizing mutations translates too many generations of plants, a process which is usually very long, sometimes even exceeding a decade. Besides that, screening and selection of mutants pose high resource demand, and thus infrastructure may be a limiting factor in low-resource settings (Shu Q. Y., 2012& Forster B. P., 2012).

In IPCC context, the major challenges in India are agriculture-climate conditions and economic and social status of farmers. Indian farmers are mostly smallholders having limited resources so they find it hard to afford with new technologies and practices. Additionally, India's native agro-climatic diversity necessitates development of crop varieties adapted to different regions, which increases the complexity of utilizing mutation breeding tool (Sikka V. K. & Saini R. G., 2014).

To overcome these constraints, mutant breeding is a way for the crop improvement and contribute to food security in India. This approach must be complemented by various varieties of plant breeding and be accompanied by suitable policies and investments(Bhatia, S., Bhatia, N., and Sharma, K., 2016)

VI. FUTURE PROSPECTS: MUTATION BREEDING - TOOL FOR SUSTAINABLE AGRICULTURE

Mutation breeding, or mutagenesis, has a lot of prospect as a tool of a sustainable agriculture in India due to its numerous agro-climatic zones and the requirement of improved crop varieties. This tactic helps to obtain enhanced resistance against diseases and pests, abiotic stresses such as drought, salinity and extreme temperatures in crop-varieties. Climate change and the growing pressure on agricultural resources are the highlights in which determining these traits are important.

But, the effective use of the mutation breeding to achieve the sustainable agriculture in the Indian context needs to take into account multiple factors. For the start, it involves improving knowledge in the field of plant genetics and the theory about mutation. This information supports predicting and restraining the implications of mutations, so that the application of mutation breeding works well. Gene mapping and bioinformatics facilitate this process. Another is that mutation breeding needs to be harmonized with the other plant breeding methods, such as hybridization and marker assisted selection. This integrated approach is possible by combining various methods together and enhancing the success for designing new improved varieties of crops. For example, mutation breeding is responsible for inducing genetic variation across species and marker-assisted supporting in identifying and keeping only beneficial mutations.

Thirdly, the utilization of mutation breeding demands remarkable resources, irrespective of time, human labor, and infrastructural support. Therefore, the right policies and resources need to be in place. Here we refer for instance, to the funding of research and development, capacity strengthening of researchers and farmers, and the creation of infrastructure for mutation breeding and screening of mutants. At last, the socio-economic situation about farmers needs to be taken into account. The majority of farmers in India are the smallholders with less resource and they find it difficult to accept the new technologies and the practices. This implies that mechanics need to be put in place to ensure that benefits of mutation breeding are readily available for these farmers.

VII. THE PATH FORWARD FOR MUTATION BREEDING IN INDIA

The future of mutation breeding in India crucially goes along with different important factors and strategies.

On the first hand, the issue of uncertainty and randomness of the mutations might show to be solve by means of technological progress and deep plant genetics understanding. Using such approaches as, the application of molecular markers and genomic selection may be relevant to detecting positive mutations and facilitating the breeding process.

Moreover, the resource-dependent character of mutation breeding can be dealt with through engineering efficient screening and selection standards and the application of biotechnology to speed up the breeding. Thus, the agro-climatic conditions

specific to the farming system in India and the socially and economically defined predictions of the agriculture in India must be taken into consideration. This calls for developing novel crop types that are climate-smart, locally tailored and easy to accept by small-scale farmers. In fact, farmers too should be given training and support as and when required for their ability to adapt new technologies and techniques. Besides the mutation breeding, plant breeding is one of the main techniques that can be used in combination with other breeding techniques. This could mean the application of the traditional breeding methods as well as the advanced ones such as genetic engineering and genome editing. Finally, effective policies and investments will also help in increasing security. This could cover such areas as research and development funding as well as acceptance policies of new and improved cropping patterns.

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