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Mutation Breeding in Sorghum (*Sorghum bicolor* L.): A Review of Mutagenic Effectiveness, Genetic Variability and Crop Improvement

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Sorghum (*Sorghum bicolor* L. Moench) is an important cereal crop cultivated widely in semi-arid and drought-prone regions for food, feed and biofuel purposes. However, limited genetic variability in cultivated sorghum restricts its improvement through conventional breeding. Mutation breeding has emerged as an effective approach to induce genetic variability and improve economically important traits. The present review summarizes the findings of several studies on mutation breeding in sorghum using physical and chemical mutagens such as gamma rays and ethyl methane sulfonate (EMS). Research findings indicate that mutagenic treatments significantly increase genetic variability in sorghum for traits such as plant height, flowering time, grain yield and stress tolerance. Chlorophyll mutations in the M_2 generation serve as reliable indicators for evaluating mutagenic effectiveness and efficiency. Combined treatments of gamma rays and EMS have shown higher mutation frequency and wider mutation spectrum compared to individual treatments. Several beneficial mutants including early flowering, dwarf types and high yielding lines have been identified and validated in later generations. Mutation breeding programs have also contributed to the development of improved sorghum varieties with enhanced adaptability and productivity. Overall, induced mutagenesis remains a valuable tool for sorghum improvement and can complement conventional breeding programs to address challenges related to climate change, food security and crop productivity.

Keywords: Mutation breeding, Sorghum bicolor, Gamma rays, Ethyl methane sulfonate (EMS), Genetic variability, Chlorophyll mutation, Crop improvement

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is one of the most important cereal crops cultivated in tropical and subtropical regions. It ranks fourth among major cereals after rice, wheat and maize and is widely grown in semi-arid areas due to its high drought tolerance and adaptability to harsh environmental conditions. Sorghum serves as an important source of food, animal feed and industrial raw material, including bioethanol production. Despite its importance, the productivity of sorghum remains relatively low due to limited genetic variability and susceptibility to various biotic and abiotic stresses. Improvement through conventional breeding methods is often slow because of the narrow genetic base of cultivated varieties. Therefore, generating new genetic variability is essential for effective crop improvement programs. Mutation breeding is a widely used technique for creating genetic variability by inducing heritable changes in plant genomes. Physical mutagens such as gamma rays and chemical mutagens such as ethyl methane sulfonate (EMS) have been successfully applied to induce mutations in several crop species including sorghum. These mutagens can produce a wide range of genetic alterations, from point mutations to chromosomal changes, which may lead to desirable agronomic traits. Mutation breeding has already contributed significantly to crop improvement worldwide, with thousands of mutant varieties released in different crops. In sorghum, induced mutations have been utilized to develop improved varieties with enhanced yield potential, early maturity, improved nutritional quality and tolerance to environmental stresses. This review summarizes the major findings from recent studies on mutation breeding in sorghum, focusing on mutagenic effectiveness, mutation frequency, induced variability and the role of mutagenesis in crop improvement.

Mutation Breeding in Sorghum

Mutation breeding involves the induction of genetic variation using mutagenic agents followed by selection of desirable mutants. In sorghum, both physical and chemical mutagens have been widely used to generate variability for agronomic traits. Physical mutagens such as gamma rays cause DNA damage including chromosomal breaks and large genetic rearrangements, while chemical mutagens like EMS induce point mutations by altering nucleotide sequences. These mutations can lead to morphological, physiological and biochemical changes in plants, which may be beneficial for crop improvement. Mutation breeding is particularly useful in improving specific traits of well-adapted varieties without altering their overall genetic background. It provides an effective way to enhance productivity, stress tolerance and quality traits in sorghum cultivars.

Mutagenic Treatments and Experimental Approaches

Several studies have evaluated the effects of gamma rays, EMS and their combinations on sorghum. Different doses of gamma rays ranging from 100 Gy to 400 Gy and EMS concentrations from 0.1% to 0.4% have been used to induce mutations in various sorghum genotypes. The treated seeds are usually grown in the M_1 generation to study mutagenic effects on germination and survivability, while the M_2 generation is used for detecting visible mutations and evaluating genetic variability. Increased doses of mutagens generally lead to reduced germination and plant survival due to physiological damage caused by radiation or chemical treatment. Studies have shown that the lethal dose (LD_{50}), which indicates the dose causing 50% reduction in survival, varies depending on the genotype and type of mutagen used. For example, LD_{50} values for gamma rays in sorghum were reported around 269–281 Gy, whereas EMS treatments showed LD_{50} values near 0.32–0.33%. Selection of appropriate mutagen doses is essential to achieve an optimal balance between mutation frequency and plant survival.

Table 1. Common mutagen treatments used in sorghum mutation breeding

Mutagen Type	Dose/Concentration	Purpose
Gamma rays	100–400 Gy	Induce chromosomal mutations
EMS	0.1–0.4%	Induce point mutations
Gamma rays + EMS	Combined treatments	Increase mutation frequency
Sodium azide	0.01–0.03%	Chemical mutagenesis

Chlorophyll Mutations as Indicators of Mutagenic Activity

Chlorophyll mutations are widely used to evaluate the effectiveness of mutagenic treatments in plants. These mutations are easily visible during the seedling stage and help measure mutation frequency. Common chlorophyll mutants observed in sorghum include:

- Albino
- Xantha
- Chlorina
- Viridis
- Xanthaviridis

Among these, albino mutants are most frequently observed. These seedlings lack chlorophyll and usually die shortly after germination.

Table 2. Types of chlorophyll mutants reported in sorghum

Mutation Type	Characteristics
Albino	Completely white seedlings lacking chlorophyll
Xantha	Yellow colored seedlings
Chlorina	Light green seedlings
Viridis	Deep green seedlings
Xanthaviridis	Yellowish-green leaves

Mutagenic Effectiveness and Efficiency

Mutagenic effectiveness and efficiency are important parameters used to evaluate the success of mutation breeding experiments. Mutagenic effectiveness refers to the frequency of mutations induced per unit dose of mutagen, whereas mutagenic efficiency measures the proportion of useful mutations relative to biological damage such as lethality or sterility. Research studies have shown that combined treatments of gamma rays and EMS often exhibit higher mutagenic effectiveness and efficiency compared to individual treatments. For example, the treatment combination of 100 Gy gamma rays with 0.1% EMS showed high mutagenic efficiency in sorghum populations. Similarly, moderate doses of gamma rays (around 300 Gy) and EMS (around 0.2%) were found to be effective in generating a wide range of genetic variability for important agronomic traits.

Induced Genetic Variability and Mutant Identification

Mutation breeding has successfully generated a wide range of genetic variability in sorghum populations. Significant variation has been observed for traits such as plant height, flowering time, panicle length, grain yield and maturity period. Several beneficial mutants have been identified in mutation breeding studies. These include dwarf mutants, brown midrib mutants, early flowering lines and high yielding genotypes. Such mutants can be used directly as improved varieties or as parental lines in breeding programs. In addition, mutation breeding has also contributed to improving sorghum adaptation to environmental stresses. Screening programs have identified mutants with improved drought tolerance and better growth performance under stress conditions.

Role of Mutation Breeding in Sorghum Improvement

Mutation breeding has played a significant role in enhancing sorghum productivity and adaptability. Several mutation breeding programs have successfully developed improved sorghum varieties with better yield potential and stress tolerance. For example, mutation breeding programs conducted in Indonesia have produced improved sorghum varieties that contribute to food and energy security in drought-prone regions. These varieties show better adaptability, productivity and tolerance to environmental stress conditions. Mutation breeding is particularly useful for improving traits that are difficult to modify through conventional breeding, such as grain quality, plant architecture and resistance to environmental stresses. Furthermore, induced mutations provide valuable genetic resources for molecular studies and functional genomics in sorghum.

Future Prospects

Advances in molecular biology and genomic technologies have opened new opportunities for mutation breeding in sorghum. Modern techniques such as molecular markers, genome sequencing and mutation detection methods can help identify beneficial mutations more efficiently. Integration of mutation breeding with molecular breeding and genomic tools can accelerate the development of improved sorghum varieties. Additionally, mutation breeding can play an important role in addressing global challenges such as climate change, food security and sustainable agriculture.

Conclusion

Mutation breeding has proven to be an effective strategy for generating genetic variability and improving agronomic traits in sorghum. The use of physical mutagens such as gamma rays and chemical mutagens such as EMS has resulted in the induction of diverse mutations affecting morphological, physiological and yield-related traits. Chlorophyll mutations in the M_2 generation serve as reliable indicators for evaluating mutagenic effectiveness and efficiency. Combined mutagenic treatments have been shown to enhance mutation frequency and broaden the spectrum of induced variability. Several useful mutants including early flowering, dwarf and high yielding lines have been successfully identified and utilized in breeding programs. Overall, mutation breeding continues to be a valuable tool for sorghum improvement and holds great potential for developing resilient and high-yielding varieties suitable for future agricultural challenges.

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