2024 International Nuclear Atlantic Conference – INAC 2024
Escola de Guerra Naval, Rio de Janeiro, RJ,May6 - 10, 2024

ISBN: 978-65-594-1256-3

Applying irradiation technology in seeds to improve harvest performance: Challenges and potential responses

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1. Introduction

The Food and Agriculture Organization (FAO) of the United Nations estimates that to meet the food needs of a growing population, global food production will need to increase by approximately 50% by 2050 compared to 2012 levels.[1] This scenario would displace a significant amount of food production. A good harvest starts with a good choice of seeds.Seed irradiation is a technique used in agriculture to induce mutations and generate varieties with desirable characteristics. Plants derived from this technology that present the desired characteristics are selected for future crossings and development of new varieties .

Since the 1960s, gamma rays have been used as a mutagen in seeds that are typically treated for seconds to minutes with a source of cobalt-60 or irradiated in x-ray machines .This process is known as radiation-induced mutagenesis .Irradiation of seeds can be carried out in the range of doses recommended by the IAEA up to 10 kGy .These radiations have enough energy to cause damage to cell DNA, leading to mutations. After irradiation, the mutated seeds are germinated and the resulting plants are evaluated for desired traits.

The idea behind this method is to create genetic variability in plants, which can result in traits such as disease resistance, greater fruit production, better adaptation to adverse climatic conditions, among others.

Seed irradiation, due to its nature and technological inherentness, needs approval, commitment and scientific parameters to be applied on a scale.This review aims to provide an overview of recent advancements in seed irradiation, focusing its applications and challenges and potential responses on crop improvement.

1.1 Effects of gamma irradiation and seed mutagenesis

Radiation can be ionizing, such as X-rays, gamma rays, or alpha and beta particle radiation.Gamma radiation affects the plant growth and induces change in genetic level, physiological, biochemical and morphological nature of the cells. Gamma radiation induces biochemical changes and breakdowns the bond in between chains, cross-linking in DNA molecules and protein molecules. Protein, carbohydrate and vitamins are necessary for the seedling development. Based on the gamma radiation doses, various morphological and biochemical characters altered and induced and stimulate seedling growth and enhanced germination[2].Gamma irradiation induces more mutants such as chlorophyll mutants, leaf and viable mutants in all crop plants. In many crops, gamma irradiation enhances the protein and amino acids in seeds and it enhances the yield traits.

The aim of seed breeding based on irradiation-induced genetic mutations is to develop and improve plant varieties by modifying one or two main traits to increase the desired quality. Physical and chemical mutagenesis is used to induce mutations in seeds and selection for desired agronomic traits is done in the first generation, where most mutant lines can be discarded. The desired characteristics are confirmed in the second and third generations through stable phenotypic evidence, other evaluations are carried out in the following generations.Figure l

2. Methodology

To obtain the information for this work, we used a literature search compiling a list of studies investigating the use of nuclear technology in seeds, the databases used were the platforms: Scopus, ScienceDirect and institutional texts published electronically by the IAEA– to 2012 until December 31, 2023.These keywords were used for the research: *seed irradiation; irradiated seeds; crop improvement.*The protocol aimed to identify published scientific studies that investigated irradiated seeds (commodities) and identify which studies addressed the positive effects of irradiation on seed quality, germination and resistance to pests and diseases. The basic method used in this research is the description analysis method.Relevance was assessed by reading the title and summary of the article .All articles (N =19) were then read in full.

2.1 Data extraction and analysis

The selected studies were systematically reviewed, and relevant data were extracted. Key findings related to seed quality, germination rates, and crop performance were analyzed to identify common trends and variations,and checked there is the potential use of seed irradiation as a practicable and applicable approach, together with agricultural biotechnology,according the figure II

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3. Results and Discussion

According to IAEA institutional text, located in the chapter dedicated to nuclear applications in agriculture, natural means to induce genetic diversity have been exploited for many millennia to improve major food crops.

However, the frequency of such mutations is insufficient to meet current needs. One of the most important breakthroughs in the history of genetics was the discovery that mutations can be induced by physical and chemical mutagens (agents that change the genetic material of an organism). Mutation induction, together with mutation detection a key element of mutation breeding, has been an important tool for plant breeders for more than 70 years to increase the genetic diversity of plants and derive new mutant lines with improved characteristics.

Scientific understanding of the numerous nuances of seed irradiation is important for environmental protection and nowadays especially for food production, for agriculture, since United Nations projections suggest that the global population could reach around 8, 5 to 9.7 billion people by 2030.
The Department of Nuclear Energy Sciences and Applications (DNSA), as described on iaea.org, covers a wide range of socioeconomic sectors, from health, food and agriculture, among others, and works to help Member States meet their development needs through nuclear science, technology and innovation, with the aim of contributing to global food security and sustainable agricultural development around the world.
Adaptation strategies include changing land and cropping practices, the development of improved crop varieties, implementation of integrated production systems, broad-based genetic resources, is a key strategy to reduce risks [3,4].
Much of our knowledge about the effects of ionizing radiation exposure on plants is based on high-dose studies. Data relating to the production of studies on seed technology and harvest performance until 2023 both in academic research and in field application conditions, as can be seen according to the compilation described in table I.

Existing studies and relevant applications of radiation biology disclose the prominent effects of uniformity of radiation dose. For example, low dosage uniformity may induce excessive deaths (seeds with relatively high dosage) and decrease of seed mutagenesis rate (seeds with relatively low dosage) in radiation breeding. Mutation breeding has played a crucial role to enhance the world food security, hence new crop varieties induced by the utilization of various mutagens have contributed to the significant enhancement of crop production[5].
Seed irradiation has demonstrated significant potential in improving crop performance across various crops. Gamma irradiation induced more morphological variation from the seedling stage to growth stage. Gamma irradiation induced various morphological, biological and physiological changes in different crop plants. It alters the quantitative and qualitative traits in successive generations.
A highly significant positive correlation was observed between total fruit per plant, total number of fruit per plant, plant height, fruit fresh weight, number of secondary branches, chlorophyll a, fruit dry weight, total chlorophyll content, stem diameter, fruit length and fruit girth. [6].
With increasing chronic gamma dose, mutagenic efficiency and efficacy generally increased.Additionally, studies highlighted the positive impact of irradiation on the storage stability of seeds, reducing losses due to pests during storage. These findings collectively support the notion that seed irradiation can be a valuable tool in sustainable.

4. Conclusions

We trust that analytics and arguments will stimulate demystification, constructive dialogue with the scientific community on the ways of applying nuclear technology in seeds . Based on this review, gamma irradiation proved to be more effective and efficient mutagen to improve the quantitative and qualitative traits, especially seed size and seed yield in the breeding programme to develop new varieties of crops What is the method that should be approached for the implementation of a real (large-scale) option of seed irradiation technology,and be used as na option that hasal ready been studied and established to provide a significant increase in food production.

Acknowledgements

The authors are grateful to Comissão Nacional de Energia Nuclear (CNEN, Brazil), Instituto de PesquisasEnergéticas e Nucleares (IPEN, Brazil), (CAPES,Brazil)and Conselho Nacional de DesenvolvimentoCientífico e Tecnológico (CNPq, Brazil) for technical and financial support.

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