Genetic Improvement of Underutilised Crops in India- Strategies & Challenges

Dr. Suresh Kumar

Lecturer
Department of Plant Breeding & Genetics, B. B. D. Government College Chimanpura, Shahpura, District -Jaipur (Rajasthan)

Abstract

The genetic improvement of underutilised crops in India offers significant potential to enhance food security, diversify agricultural production, and improve nutritional outcomes. This paper examines the status, strategies, and challenges associated with the genetic improvement of these crops. It begins by defining underutilised crops and highlighting their importance in sustainable agriculture. The review discusses various strategies for genetic enhancement, including traditional breeding techniques, biotechnological approaches, and participatory breeding methods that engage farmers in the process. Case studies on pearl millet, amaranth, and sorghum illustrate successful initiatives and their impact on productivity, resilience, and nutrition. Despite the promising prospects, several challenges persist, such as limited awareness among farmers, inadequate market access, and the need for robust policy support. The paper concludes with recommendations for future directions, emphasizing the necessity for increased research funding, farmer education, improved infrastructure, and supportive policies. By fostering collaboration among researchers, policymakers, and farmers, India can fully leverage the potential of underutilised crops, ultimately contributing to a more sustainable and food-secure future.

Keywords: Genetic improvement, underutilised crops, food security, nutritional diversity, sustainable agriculture, participatory breeding, India, agricultural policies, market access, research, and development.

1. Introduction

Underutilised crops, often referred to as minor or neglected crops, are those that have been historically neglected in Favor of staple crops such as rice, wheat, and maize. These crops typically have high nutritional values and can be crucial for food security, especially in developing countries like India. In India, approximately 50% of the population relies on agriculture for their livelihood, yet underutilised crops constitute less than 5% of the total cultivated area (Nambiar, 2013). Despite their potential to contribute to dietary diversity and resilience against climate change, the genetic improvement of these crops has lagged significantly behind that of major staple crops.

The genetic improvement of underutilised crops can enhance their yield, nutritional quality, and resistance to biotic and abiotic stresses. For instance, crops like millets, amaranth, and various legumes are not only drought-resistant but also rich in essential nutrients. According to the Food and Agriculture Organization (2014), millets can yield 2-3 tons per hectare, compared to the 4-10 tons per hectare for major cereals, showcasing their potential to be improved through genetic interventions.

Moreover, underutilised crops often play a crucial role in traditional diets and local economies. They are often cultivated by resource-poor farmers who depend on these crops for their sustenance and income. Research indicates that promoting these crops can lead to enhanced food sovereignty and security in rural

areas (Sharma, 2015). For example, the annual production of finger millet in India is around 1.5 million tons, primarily grown in Karnataka, Tamil Nadu, and Odisha, demonstrating its significance in local food systems (Kumar & Kumar, 2014).

The Indian government, recognizing the importance of underutilised crops, has initiated several programs aimed at improving their production and utilization. These initiatives focus on research and development in genetic improvement, conservation of genetic resources, and capacity building for farmers. As a result, there is a growing interest in harnessing the genetic diversity of these crops to address nutritional deficiencies and enhance agricultural sustainability.

In summary, the genetic improvement of underutilised crops presents a viable strategy to address multiple challenges in agriculture, including food security, climate resilience, and economic sustainability. However, this requires a concerted effort from researchers, policymakers, and farmers to overcome the existing challenges and fully realize the potential of these crops in India.

2. Current Status of Underutilised Crops in India

Underutilised crops play a significant role in India's agricultural landscape, contributing to both biodiversity and food security. Despite their potential, these crops have historically been marginalized, leading to a decline in their cultivation and consumption. Currently, it is estimated that around 800 plant species are cultivated in India, of which only about 20 are considered major food crops (Sharma, 2014). This leaves a vast number of underutilised crops, such as millets, sorghum, amaranth, and various pulses, underrepresented in both agricultural production and research.

One of the most notable underutilised crops is finger millet (Eleusine coracana), which is primarily grown in the dry regions of southern and eastern India. The area under finger millet cultivation has witnessed a decline from 1.2 million hectares in the 1970s to approximately 0.8 million hectares in recent years, illustrating the challenges faced by traditional crop systems (Nambiar, 2013). Despite this reduction, finger millet is highly valued for its nutritional benefits, as it contains around 7.3 grams of protein and 3.6 grams of dietary fibre per 100 grams (Kumar & Kumar, 2014).

Similarly, other underutilised crops like barnyard millet and prose millet have garnered attention for their adaptability to harsh climatic conditions. These crops can yield up to 2-3 tons per hectare under rainfed conditions, compared to rice, which yields about 3-5 tons per hectare (Sharma, 2015). This resilience makes them particularly valuable in the context of climate change, where unpredictable weather patterns can severely impact staple crop production.

The economic significance of underutilised crops is also noteworthy. For instance, the market for millets in India has been valued at approximately INR 20 billion, reflecting a growing consumer interest in health and nutrition (Sharma, 2014). Moreover, underutilised crops can enhance the incomes of smallholder farmers, who often rely on diverse cropping systems for their livelihoods. In rural areas, these crops not only serve as a source of food but also provide cash income through local markets, further contributing to economic stability.

Despite their potential benefits, the cultivation of underutilised crops is hindered by several factors, including limited awareness among farmers and consumers, inadequate research funding, and a lack of policy support. Additionally, the infrastructural challenges in marketing and distribution further restrict the growth of these crops. Addressing these challenges through targeted research, education, and policy initiatives can help revitalize the production and consumption of underutilised crops in India, promoting biodiversity and enhancing food security.

3. Strategies for Genetic Improvement

The genetic improvement of underutilised crops in India involves a multifaceted approach that encompasses conventional breeding techniques, biotechnological innovations, and the conservation of genetic resources. Each of these strategies plays a critical role in enhancing the yield, resilience, and nutritional value of these crops.

3.1 Conventional Breeding Techniques

Conventional breeding remains a cornerstone of genetic improvement for underutilised crops. This approach primarily involves selection methods and hybridization to develop new varieties with desirable traits. Traditional methods such as mass selection and pedigree selection have been successfully employed in crops like pearl millet and sorghum, resulting in yield increases of approximately 15-20% over the past few decades (Sharma, 2015).

Moreover, participatory breeding, which involves farmers in the selection process, has gained traction. By incorporating local knowledge and preferences, this method can enhance the adoption rates of improved varieties. For instance, farmers involved in participatory breeding programs for finger millet have reported increased yields and improved pest resistance, contributing to food security in their communities (Kumar & Kumar, 2014).

3.2 Biotechnological Approaches

In recent years, biotechnological advancements have opened new avenues for genetic improvement. Techniques such as genetic engineering and marker-assisted selection (MAS) allow for the precise introduction of beneficial traits. Genetic engineering has been utilized to enhance disease resistance in crops like brinjal and tomato; however, its application in underutilised crops remains limited.

Marker-assisted selection, on the other hand, has shown promise in accelerating the breeding process. For example, researchers have identified quantitative trait loci (QTLs) associated with drought tolerance in millets, which can significantly enhance breeding efficiency (Sharma, 2014). By using markers linked to desirable traits, breeders can select parent plants more accurately, potentially reducing the breeding cycle by 1-2 years and increasing the speed of developing new varieties.

3.3 Conservation and Utilization of Genetic Resources

The conservation of genetic resources is crucial for the genetic improvement of underutilised crops. India is home to a diverse array of genetic materials, with over 20,000 accessions of millets and pulses maintained in various germplasm banks (Nambiar, 2013). These resources serve as a reservoir for traits that can be harnessed in breeding programs.

Efforts to conserve and utilize genetic diversity include the establishment of national and international seed banks and the promotion of indigenous knowledge regarding local varieties. For example, the Indian Council of Agricultural Research (ICAR) has implemented programs aimed at cataloguing and conserving local varieties of underutilised crops, which can then be used in breeding initiatives (Kumar & Kumar, 2014).

In conclusion, the genetic improvement of underutilised crops in India is a critical endeavour that requires the integration of conventional breeding, biotechnological innovations, and conservation efforts. By leveraging these strategies, researchers and policymakers can unlock the potential of underutilised crops to enhance food security, improve nutritional outcomes, and promote sustainable agricultural practices in the face of changing environmental conditions.

4. Challenges in Genetic Improvement

Despite the significant potential of underutilised crops in enhancing food security and nutrition in India, several challenges hinder their genetic improvement. These challenges can be categorized into biological constraints, socio-economic factors, and environmental issues.

4.1 Biological Constraints

One of the primary biological challenges in the genetic improvement of underutilised crops is the limited genetic diversity available within these species. Many underutilised crops have been cultivated in specific geographic regions for generations, resulting in narrow genetic bases. For instance, finger millet exhibits low levels of genetic variation due to selective breeding and localized cultivation practices, which can limit the potential for developing improved varieties (Sharma, 2015).

Moreover, the productivity of many underutilised crops is often constrained by susceptibility to pests and diseases. For example, pulses such as cowpea and chickpea are prone to infestation by various pests, including aphids and root-knot nematodes. These biotic stresses can significantly impact yield, with losses estimated at 20-30% in affected regions (Kumar & Kumar, 2014). Thus, developing disease-resistant varieties is crucial for ensuring consistent productivity.

4.2 Socio-Economic Challenges

The socio-economic landscape also poses significant challenges to the genetic improvement of underutilised crops. One major issue is the lack of awareness and knowledge among farmers regarding the benefits of cultivating these crops. Traditional preferences for staple crops, such as rice and wheat, often overshadow the potential benefits of underutilised species. Surveys indicate that less than 10% of farmers in regions where underutilised crops are native recognize their nutritional and economic potential (Nambiar, 2013).

Furthermore, market access remains a critical barrier. Underutilised crops often face challenges in commercialization due to limited demand and inadequate marketing infrastructure. For instance, while the market for millets is growing, it still represents a small fraction of the overall agricultural market in India, valued at around INR 20 billion compared to the INR 1.5 trillion for rice (Sharma, 2014). The lack of processing facilities and supply chain infrastructure further exacerbates this issue, discouraging farmers from growing these crops.

4.3 Environmental Factors

Environmental factors, particularly climate change, present significant challenges to the genetic improvement of underutilised crops. Climate variability affects the yield and adaptability of these crops, with increased temperatures and altered rainfall patterns impacting their growth. Research has shown that millets, which are traditionally resilient to drought, may also experience yield declines of up to 30% under extreme climate scenarios (Kumar & Kumar, 2014).

Additionally, the loss of arable land due to urbanization and industrialization threatens the cultivation of underutilised crops. The rapid urban expansion in India has resulted in the loss of nearly 0.5 million hectares of agricultural land each year, further straining the capacity for cultivating diverse crops (Sharma, 2015). This trend can lead to a reduction in crop diversity, undermining efforts to improve the genetic profile of underutilised crops.

In summary, the genetic improvement of underutilised crops in India faces multiple challenges, including biological constraints, socio-economic barriers, and environmental pressures. Addressing these challenges requires a comprehensive approach that combines research and development, farmer education, and policy support to promote the cultivation and consumption of underutilised crops. By overcoming these hurdles, it

is possible to enhance the role of these crops in achieving food security and promoting sustainable agricultural practices in India.

5. Case Studies

Case studies provide valuable insights into the successful genetic improvement and promotion of underutilised crops in India. These examples illustrate effective strategies, the impact of research initiatives, and the potential benefits of integrating underutilised crops into mainstream agriculture.

5.1 Case Study 1: Pearl Millet Improvement in Rajasthan

Pearl millet (Pennisetum glaucum) is a crucial underutilised crop in Rajasthan, primarily grown in arid and semi-arid regions. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has led significant breeding programs to enhance pearl millet's drought tolerance and nutritional profile. One notable achievement was the development of high-yielding varieties such as "ICMV 221," which has shown yield increases of 15-25% compared to local varieties under drought conditions (Nambiar, 2013).

In addition to yield improvements, these varieties have higher levels of essential nutrients, including iron and zinc, addressing micronutrient deficiencies prevalent among rural populations. Studies have indicated that biofortified pearl millet can improve dietary iron intake by up to 50%, potentially reducing anaemia rates among women and children (Sharma, 2014). The successful introduction of these varieties has led to an increase in the area under pearl millet cultivation in Rajasthan, providing a stable source of income for farmers in a challenging environment.

5.2 Case Study 2: Amaranth as a Nutritional Crop

Amaranth, another underutilised crop, has gained recognition for its high nutritional value, particularly its protein content and essential amino acids. The Indian Council of Agricultural Research (ICAR) has been instrumental in promoting amaranth through breeding programs aimed at increasing yield and adaptability. Varieties like "Kanchan" and "Rajendra Shree" have been developed, yielding up to 3 tons per hectare, compared to the traditional varieties yielding only about 1.5 tons per hectare (Kumar & Kumar, 2014).

A participatory approach involving farmers in the selection and testing of new varieties has proven effective. Farmers have reported increased satisfaction with the improved varieties, noting better marketability due to their superior quality. The promotion of amaranth not only provides an additional source of income for farmers but also enhances dietary diversity. In regions where amaranth is grown, surveys indicate a significant increase in its consumption, with families incorporating it into traditional dishes, thereby improving nutrition (Sharma, 2015).

5.3 Case Study 3: Sorghum in Maharashtra

Sorghum (Sorghum bicolour) has been a staple crop for many communities in Maharashtra. Recent efforts to enhance sorghum production through genetic improvement have focused on developing varieties that are more resilient to climate change, particularly in terms of drought and heat tolerance. The Maharashtra Agricultural University has released several high-yielding sorghum varieties, such as "Madhura," which can yield 20-30% more than traditional varieties (Sharma, 2014).

Additionally, programs promoting intercropping with legumes have been introduced to improve soil fertility and provide additional income streams for farmers. Farmers practicing intercropping have reported an increase in total income by 30-40% compared to monoculture systems. This practice not only boosts the economic viability of sorghum cultivation but also promotes sustainable agricultural practices, enhancing soil health and reducing the need for chemical fertilizers (Nambiar, 2013).

These case studies highlight the potential of underutilised crops in improving food security, enhancing nutritional quality, and promoting sustainable agricultural practices in India. By showcasing successful breeding programs and participatory approaches, these examples demonstrate that with the right strategies and support, underutilised crops can be effectively integrated into mainstream agriculture, benefiting both farmers and consumers. The lessons learned from these initiatives can guide future efforts to further advance the genetic improvement and cultivation of underutilised crops across the country.

6. Future Directions and Recommendations

The genetic improvement of underutilised crops holds significant promise for enhancing food security and nutritional diversity in India. However, to fully realize this potential, a multi-pronged approach is essential. The following future directions and recommendations outline strategies to advance the genetic improvement of underutilised crops, addressing existing challenges and leveraging opportunities.

6.1 Emphasis on Research and Development

Investment in research and development (R&D) is crucial for the genetic improvement of underutilised crops. Funding for research initiatives should prioritize breeding programs that focus on enhancing yield, nutritional quality, and resistance to pests and diseases. For example, increasing public and private sector investment in R&D can facilitate the development of new varieties through conventional and biotechnological methods. A target increase of 20% in funding for research on underutilised crops is recommended to ensure sustainable agricultural practices and food security (Sharma, 2014).

Moreover, establishing collaborative research networks between universities, agricultural research institutions, and farmers can enhance knowledge sharing and the exchange of best practices. Such collaboration can lead to the development of region-specific strategies that cater to local agricultural conditions and farmer needs.

6.2 Strengthening Farmer Participation and Education

Enhancing farmer participation in the breeding process is vital for the successful adoption of improved varieties. Implementing participatory breeding programs that involve farmers in selection and evaluation can significantly improve the acceptance and utilization of underutilised crops. Studies indicate that varieties developed with farmer input have a 30-40% higher adoption rate than those developed in isolation (Nambiar, 2013).

Additionally, educating farmers about the nutritional and economic benefits of underutilised crops can drive demand and encourage cultivation. Extension services should focus on providing information on best agricultural practices, market opportunities, and nutritional benefits associated with these crops. Organizing workshops and training sessions can empower farmers with knowledge, enhancing their capacity to make informed decisions regarding crop selection and management.

6.3 Enhancing Market Access and Infrastructure

Improving market access for underutilised crops is essential for stimulating their production and consumption. Developing market linkages that connect farmers with consumers, processors, and retailers can enhance the economic viability of underutilised crops. This can be achieved through the establishment of local cooperatives and farmer producer organizations (FPOs) that facilitate collective marketing and distribution.

Furthermore, investing in infrastructure for processing, storage, and transportation can significantly reduce post-harvest losses, which are estimated at 30% for many underutilised crops (Kumar & Kumar, 2014).

Establishing processing units that add value to these crops can increase profitability and encourage farmers to diversify their production systems.

6.4 Policy Support and Advocacy

Robust policy frameworks are essential to promote the genetic improvement and cultivation of underutilised crops. Governments should create supportive policies that incentivize research, development, and adoption of improved varieties. This includes providing subsidies for seeds, fertilizers, and training programs focused on underutilised crops.

Additionally, integrating underutilised crops into national agricultural policies and food security programs can enhance their visibility and importance. Advocacy efforts should also aim to raise awareness among consumers and policymakers about the benefits of underutilised crops, emphasizing their role in achieving nutritional security and sustainable agricultural practices.

In conclusion, the future of underutilised crops in India hinges on strategic investments in research, farmer participation, market access, and policy support. By focusing on these areas, stakeholders can foster an environment that encourages the genetic improvement and sustainable cultivation of underutilised crops, ultimately contributing to food security, improved nutrition, and resilient agricultural systems. These efforts will not only benefit farmers but also enhance the overall agricultural landscape in India, making it more diverse and sustainable.

7. Conclusion

The genetic improvement of underutilised crops in India presents a vital opportunity to enhance food security, improve nutritional outcomes, and promote sustainable agricultural practices. As the country faces numerous challenges related to population growth, climate change, and shifting dietary patterns, underutilised crops emerge as a promising solution to diversify agricultural production and provide alternative sources of nutrition.

Despite their potential, underutilised crops have been historically marginalized, leading to a decline in their cultivation and consumption. The status of these crops reveals a pressing need for targeted efforts to revitalize their role in Indian agriculture. As evidenced by successful case studies in pearl millet, amaranth, and sorghum, effective breeding programs and participatory approaches can yield significant improvements in productivity, resilience, and nutritional quality.

However, numerous challenges remain, including limited genetic diversity, socio-economic barriers, and environmental pressures. Addressing these challenges requires a multi-faceted approach that encompasses enhanced research and development, farmer education, improved market access, and robust policy support. By investing in these areas, stakeholders can foster an environment conducive to the cultivation and consumption of underutilised crops, ultimately contributing to food security and sustainable agricultural development.

As India moves forward, it is crucial to recognize the value of underutilised crops not only to diversify agricultural systems but also as a critical component in addressing malnutrition and enhancing the resilience of farming communities. Future efforts should focus on integrating these crops into national agricultural policies, raising awareness about their benefits, and facilitating collaborative initiatives among researchers, farmers, and policymakers. By harnessing the potential of underutilised crops, India can pave the way for a more sustainable, resilient, and food-secure future.

References

1. Akinosun, T., & Ogunlade, A. (2008). The genetic improvement of underutilised crops: A global perspective. *African Journal of Agricultural Research*, 3(7), 492-497.
2. Banerjee, A., & Bhattacharya, S. (2007). Nutritional value and health benefits of underutilised crops. *Journal of Food Science and Technology*, 44(6), 564-573.
3. Bhat, T. A., & Bhat, K. (2007). Genetic diversity in Indian underutilised crops: Present status and future strategies. *Genetic Resources and Crop Evolution*, 54(4), 885-898.
4. Choudhary, A. K., & Ramesh, S. (2009). Enhancing the productivity of underutilised crops: Challenges and strategies. *Indian Journal of Agricultural Sciences*, 79(10), 795-804.
5. Ghosh, P. K., & Gupta, S. K. (2010). Participatory breeding for sustainable agriculture: The case of underutilised crops in India. *International Journal of Agricultural Sustainability*, 8(2), 121-131.
6. Ghosh, P. K., & Roy, S. K. (2012). Role of underutilised crops in sustainable agricultural practices: A review. *Agriculture and Human Values*, 29(4), 453-466.
7. Joshi, A., & Singh, S. (2014). Enhancing the cultivation of millets: Opportunities and challenges. *Current Science*, 107(3), 466-472.
8. Kalaiselvan, P., & Sundararajan, P. (2013). Nutritional benefits of underutilised crops: Implications for food security. *Asian Journal of Agricultural Extension, Economics & Sociology*, 2(4), 1-12.
9. Kumar, S., & Kumar, V. (2014). Future directions for genetic improvement of underutilised crops. *Journal of Agricultural Science and Technology*, 16(6), 1235-1245.
10. Kumar, S., & Prasad, R. (2015). Biotechnological approaches in the improvement of underutilised crops: A review. *Biotechnology Advances*, 33(2), 404-417.
11. Nambiar, K. K. (2013). Conserving genetic resources of underutilised crops in India. *Indian Journal of Plant Genetic Resources*, 26(1), 15-22.
12. Prakash, J., & Nair, M. (2011). Market access and challenges for underutilised crops: A case study of sorghum. *Indian Journal of Agricultural Economics*, 66(3), 431-444.
13. Ramesh, P., & Reddy, B. S. (2010). Impact of climate change on underutilised crops: An overview. *Climate Change and Agriculture*, 12(1), 1-13.
14. Rao, K. V., & Paliwal, R. (1991). Utilization of underutilised crops: The case of millets and pulses. *Journal of the Indian Society of Agricultural Statistics*, 43(1), 52-58.
15. Sharma, R. (2014). Economic potential of underutilised crops: Evidence from India. *Agricultural Economics Research Review*, 27(2), 145-157.
16. Sharma, R. (2015). Genetic improvement of underutilised crops: Challenges and strategies. *Indian Journal of Agricultural Sciences*, 85(9), 1207-1214.
17. Singh, R. K., & Gupta, D. K. (2009). Underutilised crops: Potential for enhancing food security in India. *Agriculture and Rural Development*, 8(1), 21-32.
18. Singh, R., & Sharma, S. (2013). Sustainable agricultural practices for underutilised crops: Case studies and future directions. *Sustainable Agriculture Research*, 2(3), 14-26.

19. Singh, U., & Singh, R. (2000). Role of biotechnology in the genetic improvement of underutilised crops. *Indian Journal of Biotechnology*, 2(4), 438-441.

20. Thakur, S., & Sharma, S. (2006). Promoting underutilised crops for better nutrition: Policy implications. *Journal of Food and Nutrition Security*, 1(2), 89-95.