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EDITED BY
Moslem Bahmankar,
Agricultural Research, Education and Extension Organization (AREEO), Iran

REVIEWED BY
Christian Keambou Tiambo,
Centre for Tropical Livestock Genetics and Health, Kenya
Naglaa A. Abdallah,
Cairo University, Egypt
Kassahun Tesfaye,
Addis Ababa University, Ethiopia
Homa Zarabizadeh,
Shahid Beheshti University, Iran

*CORRESPONDENCE
Olalekan Akinbo
✉ akinbooa@gmail.com

†These authors have contributed equally to this work

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The role of young scientists in promoting genome editing for sustainable agriculture and food systems in Africa

Seleman Yusuph Kitenge[1†], Bongani Nkhabindze[1], Billy Omboki Ratemo[1], Susan Angira Dada[1], Ejeoghene Rita Ogbimi[2,3†], Benjamin Karikari[4], Valter N. A. Nuaila[5], Mary Esther Muyoka Toili[6,7], Abigarl Ndudzo[8], Charles Oluwaseun Adetunji[9], Estherine Fotabong[1] and Olalekan Akinbo[1*]

[1]Genome Editing Programme, Directorate of Agricultural, Food Security and Environmental Sustainability, African Union Development Agency – NEPAD, Midrand, South Africa, [2]Department of Botany, Obafemi Awolowo University, Ile - Ife, Nigeria, [3]International Centre for Genetic Engineering and Biotechnology, New Delhi, India, [4]Department of Agricultural Biotechnology, University for Development Studies, Tamale, Ghana, [5]National Center of Biotechnology and Biosciences (CNBB), Maputo, Mozambique, [6]Department of Horticulture and Food Security, Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya, [7]Department of Horticulture and Food Security, Kenyatta University, Nairobi, Kenya, [8]Pan-African University, Institute of Basic Science, Technology Innovation (PAUSTI), Nairobi, Kenya, [9]Edo State University, Iyamho, Edo, Nigeria

Climate change together with Africa's growing population, threaten food systems. Improving youth participation in agricultural research and innovation, especially the use of genome editing (GEd) technology, will help address this inequality and ensure that Africa capitalizes on its youth to foster its food systems. This policy brief explores how young scientists are promoting GEd for sustainable agricultural and food systems in Africa. The brief made recommendations to improve on the youth participation in policy making processes and tackling public scepticism to promote the adoption of GEd. It concludes by calling for African governments to make a concerted effort to ensure young scientists are well-informed, supported, and actively involved in the advancement of GEd technology in agriculture in Africa. Climate change and various anthropogenic factors, coupled with Africa's rapidly growing population, pose significant threats to food systems and the agricultural sector. Challenges such as inadequate youth engagement in agricultural research, lack of funding and a lack of modern infrastructure hinder the continent's ability to achieve food security. Improving youth participation, particularly in the application of genome editing (GEd) technology, is essential for addressing these disparities and ensuring that Africa leverages its youthful demographic to enhance its food systems. This policy brief explores the pivotal role young scientists play in promoting GEd for sustainable agricultural and food systems in Africa. It highlights specific gaps, such as the need for increased investment in state-of-the-art laboratories, incubators, and mentorship programs, as well as financial assistance and scholarships for aspiring and budding researchers. Furthermore, the brief emphasizes the importance of youth involvement in policy-making processes and the necessity of addressing public scepticism to facilitate the adoption of GEd. By fostering an inclusive environment where young scientists are well-informed and actively engaged, African governments can harness the innovative potential of this demographic to drive agricultural advancements. The brief concludes with a call to action for African governments to prioritize the support and development of young scientists in the advancement of homegrown GEd technology, contributing to the sustainability and resilience of agriculture and food systems across the continent.

KEYWORDS
young scientists, genome editing, biotechnology, agriculture, food systems, Africa

1 Introduction

Young scientists in Africa are defined as individuals within the age bracket of 20 to 40 years who are actively engaged in scientific research, innovation, and professional development. This group encompasses a range of individuals, from the emerging talents in universities and research institutions to early-career researchers and young professionals across academia, industry, and government institutions. Within this group, "youngsters" typically refer to those in the earlier stages of their careers, such as undergraduate and graduate students or recent graduates. Meanwhile, the "older" segment (30 years and above) includes doctoral and postdoctoral researchers, as well as early-career scientists, many of whom are also involved in mentoring younger generations and contributing to the development of innovative solutions and technologies. Africa's increasing population and environmental issues, exacerbated by climate change and other anthropogenic causes, pose significant risks to the continent's food systems and the overall sustainability of the agricultural sector in pursuit of the African Union Agenda 2063 (African Union Commission, 2015; Adolph et al., 2023; Muigua, 2023; Ndudzo et al., 2024). Africa's population is projected to exceed 1.48 billion (Statista, 2024), with over 282 million people (almost 20% of the population) undernourished in 2022, reflecting an increase of fifty-seven million since the onset of the COVID-19 epidemic (FAO, AUC, ECA and WFP, 2023). Additionally, around 868 million people experienced moderate to severe food insecurity, with over one-third of this population (342 million individuals) facing severe food insecurity (FAO, AUC, ECA and WFP, 2023). This dire situation necessitates intentional actions by African nations to harness current advances, science, and technology to enhance productivity and healthy food production, thereby addressing food insecurity in Africa.

Goal 5 of Agenda 2063 advocates for *"modern agriculture to enhance production, productivity, and value addition, thereby fostering farmer and national prosperity as well as Africa's collective food security"* (African Union Commission, 2015). The Science, Technology, Innovation Strategy for Africa (STISA – 2024) further underscores the need for innovation in vital sectors, including agriculture (African Union Commission, 2020). However, a scientific research deficit exists throughout Africa (World Economic Forum, 2024). Given the pressing challenges of food insecurity in Africa, leveraging innovative solutions such as genome editing (GEd) emerges as a critical strategy to enhance agricultural productivity and resilience, addressing the continent's urgent need for sustainable food systems.

Consequently, improving the involvement of youngsters in agricultural research and innovation, particularly through the use of GEd tools can not only contribute to addressing this disparity but also guarantees that the continent capitalizes on its youthful demographic in transforming Africa's food systems. Young scientists play a pivotal role in promoting sustainable agriculture by ensuring that genome editing supports preservation and enhancement of indigenous crops and livestock while engaging communities in meaningful ways. By prioritizing local solutions and fostering collaboration between science and traditional knowledge, young scientists can contribute significantly to achieving both food security and food sovereignty in Africa's agricultural landscape (Siwior, 2021). In a nutshell, genome editing involves the alteration of genomic DNA at a precise target location across diverse cell types and organisms, encompassing the insertion, deletion, and replacement of DNA, leading to the inactivation of target genes, the acquisition of new genetic traits, and the rectification of pathogenic gene mutations (Xu and Li, 2020; Charpentier and Marraffini, 2014; Knott and Doudna, 2018). In recent years, with the fast growth of life sciences, genome editing technology has become the most effective approach to investigate gene function, examine the pathophysiology of genetic disorders, create new targets for gene therapy, breed crop varieties, and so on (Knott and Doudna, 2018; Cox et al., 2015).

By 2030, it is anticipated that young Africans will make up 42% of the total youth population worldwide, while within Africa itself, they will account for 75% of the population under the age of 35 (African Union Commission, 2019). Given the substantial population of young people, the implementation of supporting policies and initiatives for inclusive youth development is increasingly essential (African Union Commission, 2019). This will enable the continent to leverage on its dynamic, innovative, and energetic workforce to revolutionize its agricultural sector. In this context, African governments have a pivotal role in establishing conducive policies and infrastructure that enable young scientists to contribute to Research and Development (R&D) addressing the food security crisis threatening current and future generations as we pursue Africa's development blueprint of Agenda 2063. With projections indicating that Africa's population will exceed 2.5 billion by 2050 (AfDB, 2023), intentional measures are crucial to prevent exacerbating the food insecurity. This policy brief analyses the role of young scientists in promoting GEd R & D to achieve sustainable agriculture and food systems in Africa.

2 Contemporary status of genome editing in Africa and youth inclusivity in the domain

Africa faces entrenched challenges such as inadequate transport infrastructure, inadequate energy supply, poverty, and gender inequity that hinder development. The adoption and development of agricultural biotechnology in Africa is further impeded by critical scientific advancement issues including insufficient capacity in modern biotechnology among African scientists to create and implement indigenous biotech solutions (Runo et al., 2024; IEA, 2022; Baskaran and Coste, 2024), inadequate translation of upstream scientific research from advanced nations into practical applications that address real-world problems in Africa (Delmer, 2005), diminished confidence in biotechnology due to longstanding perceptions of multinational influence, and an excessively cautious regulatory approach to agricultural biotechnology (Mmbando, 2023). In addition to these problems, insufficient youth inclusiveness in GEd R & D presents additional obstacle for the future of food security and agricultural production on the continent.

While Genetically Modified Organisms (GMOs) have been a significant aspect of agricultural biotechnology since the 1990s, genome editing, particularly CRISPR/Cas, represents a more recent

advancement (Karavolias, 2022). The advent of GEd in agricultural biotechnology is now misinterpreted as a contemporary version of GMOs. Both genetic engineering (recombinant DNA technology) and GEd serve as effective processes for enhancing agricultural yields, addressing climate change, boosting food nutritional quality, advancing animal welfare, and developing products with other important characteristics (Karavolias, 2022). Although both processes intend to create novel product varieties, however, they are fundamentally distinct. For instance, according to Ahmad et al. (2023) genetic engineering is used to include novel qualities in crops by inserting genes from various species, resulting in GMOs that need stringent laws and product labeling. On the other hand, genome editing creates a single or double-strand break in the target DNA, allowing the cell to self-repair to introduce minor but researcher-intended alterations (targeted mutations), such as insertions or deletions, which may enhance gene function(s) similarly to natural mutations (Ahmad et al., 2023; Wright et al., 2016). A fragment of DNA from the same species may be included, or an existing gene may be altered without the introduction of foreign DNA into the plant genome, to confer a novel feature in plants via genome editing (Ahmad et al., 2023; Wright et al., 2016). Therefore, GEd can enhance acceptance among stakeholders and consumers.

Despite the potential of GEd, a study by Karembu (2021) indicates that most ongoing GEd initiatives and specialists in the field covering Eastern, Southern, West, Central and North Africa are led by senior scientists, with limited involvement of young scientists. This lack of young scientists' engagement raises concerns about the future trajectory of GEd research in Africa, especially given the pressing food insecurity issues on the continent. Furthermore, inadequate youth inclusion may hinder the acceptance and adoption of GEd technologies, as young people represent a significant demographic dividend and are influential in shaping narratives in digital spaces, with nearly 40% of individuals aged 15–24 in Africa active online (African Union, 2024).

Notably, AUDA-NEPAD's Policy Framework for Applications of GEd in African Agriculture emphasizes the necessity of youth inclusiveness in policy formulation and execution (AUDA-NEPAD, 2022). Engaging young scientists in research, advocacy, and policy development regarding GEd in Africa is pivotal in advancing sustainable agricultural and food systems on the continent.

Future leaders in the scientific community must recognize that research should promote societal advancement while ensuring environmental sustainability (Bugnosen, 2023). The field of modern biotechnology particularly GEd holds the potential to create innovative solutions that can mitigate climate change, enhance agriculture, bolster food security, and improve human and animal welfare. However, it is essential to ensure that the responsible application of these benefits is cultivated alongside the enthusiasm for knowledge in the next generation of scientists (Bugnosen, 2023). Therefore, this policy brief aims to highlight the critical role of young scientists in promoting the responsible use of GEd to ensure sustainable agricultural and food systems in Africa, addressing ongoing challenges of food insecurity that threaten the continent's prosperity and future.

3 Status of biotechnology education in Africa

Biotechnology education in Africa has made significant strides in recent years, but it remains unevenly developed across the continent. While some countries have established advanced programs and infrastructure, others are still in the early stages of integrating biotechnology into their educational systems. Initiatives such as the East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN) program in East Africa have contributed to building biotechnology capacity by training MSc and PhD students in areas like biosafety, agricultural biotechnology and molecular biology [Swedish International Development Cooperation Agency (SIDA), 2006]. Programs like these have strengthened institutions in countries such as Kenya, Uganda, Tanzania, and Ethiopia. Several initiatives have been launched to educate African scientists, policymakers, and regulatory experts on genome editing applications, regulations, and associated trade-offs. Among these, the Striga Smart Sorghum for Africa (SSSfA) stands out as a pioneering project. Additional training programs include TReND and NIH and GeneConvene Global Collaborative (Maeda, 2024)—Sponsored Genome Editing sessions held across various African nations. These efforts aim to reduce the risks of technology misuse by enhancing policymakers' understanding of scientific principles, enabling informed decision-making. The AUDA-NEPAD Communication and Advocacy for Genome Editing 2024 campaign features initiatives like the Genome Editing Webinar Series Workshops on "Young Scientists Leading the Way in Genome Editing" (AUDA-NEPAD, 2024b), "Science Communication on Genome Editing in Agricultural Biotechnology" (AUDA-NEPAD, 2024a), and "Integrating Genome Editing Learning Needs to Promote on-the-job Orientation in Institutions of Higher Learning," (Scientific and Industrial Research and Development Centre, 2024) and promotes dialogue in agricultural biotechnology. Centers of Excellence like BecANet (Kenya) and SANBio (South Africa) have established under the Africa Biosciences Initiative to promote research, training, and innovation in biotechnology (Makinde et al., 2009). Biotechnology education is still hindered by insufficient infrastructure, including poorly equipped laboratories and limited access to advanced technologies like genome editing tools or high throughput sequencing platforms (Mqhaba, 2024). Many universities lack interdisciplinary integration between science fields which limits the practical application of biotechnological advancements. Limited funding for research and development has resulted in a "brain drain," where skilled graduates often migrate to countries with better facilities and opportunities. Additionally, students often rely on theoretical knowledge rather than hands-on experience with modern tools such as CRISPR or next generation sequencing due to resource constraints (University of Nairobi, 2021). Access to innovative technology remains limited for many students. While some institutions collaborate with international partners to expose students to advanced methodologies, for example through sandwich programs combining local and foreign training, this is not widespread across the continent (Makinde et al., 2009). In countries like South Africa, Egypt, Nigeria, Ethiopia, Uganda, and Ghana, programs are advanced, with most universities offering specialized degrees in molecular biotechnology. However, many other countries are still developing frameworks for teaching modern biotechnology due to limited government investment and weak policy support (Makinde et al., 2009).

The scientific community in Africa consists of a mix of senior scientists and emerging young researchers. Many senior scientists have established themselves within their fields (Karembu, 2021) but often face challenges related to funding (University of Nairobi, 2021) and

institutional support leading to independent research projects. Young scientists do have opportunities to apply for grants, however, access can be competitive and limited by the availability of funding sources. Initiatives like the African Biosciences Initiative aim to enhance capacity building for young researchers through training and mentorship program. While some young scientists can lead their own projects, this is often contingent on securing funding and institutional support. The presence of networks such as BecANet and SANBio provides platforms for collaboration and resource sharing among researchers. Research funding is often insufficient, particularly for molecular biology and biotechnology projects that require significant investment in equipment and facilities. Many researchers rely on external grants form international organizations or collaborations with foreign institutions. Various international organizations including AGNES (African-German Network of Excellence in Science) Bayer research grants, funding and grants from ICGEB, DAAD, to mention but a few, provide grants aimed at supporting research initiatives. Some universities such as Makerere University in Uganda, offer scholarships specifically for post graduate students in biotechnology-related fields. Additionally, organizations like the African Union, through the African Union Commission, offer scholarships for molecular biology and biotechnology training, among others. Strengthening local research capabilities, increasing investment in education, and fostering collaboration with international partners will be essential and instrumental in attaining the mandates of the African Union Agenda 2063.

4 Recommendations

Therefore, to ensure that young scientists play a role in promoting GEd in the context of fostering sustainability in the agricultural field and food systems in Africa, this policy brief recommends the following:

a African governments are encouraged to create GEd enabling policies, legislation, regulation, or guidelines to enhance the adoption of GEd in African Union Member States. Governments should draft and publish comprehensive guidelines that outline the regulatory processes for genome editing technology. Countries like Ghana, Ethiopia, Malawi, Nigeria, Kenya, and South Africa have already made progress by publishing national biosafety guidelines that can serve as models for other nations. For example, Nigeria's national biotechnology authority allowed genome edited crops (genotypes) to be classified as conventional products provided, they do not contain foreign genetic material (Guarango, 2022; Tripathi et al., 2022; Ongu et al., 2023; Ndudzo et al., 2024).

b African governments need to invest more in the construction of innovative laboratories with access to modern tools at academic institutions that can support GEd research conducted by young scientists. This includes facilities needed for conducting CRISPR/Cas experiments such as biolistic gene gun, PCR machines, nanodrop, gel electrophoresis system, gel documentation system and centrifuge, as well as those required for sequencing like DNA sequencers and analyzers. Increased funding for research initiatives focused on genome editing can drive innovation. Governments should allocate resources to support local research institutions and universities that are developing genome edited crops tailored for Africa. To provide gifted young scientists working on GEd research projects with a supportive environment in which they can develop their research ideas, African governments need to invest in the establishment of incubation centres. Various research institutions in Africa include the International Institute of Tropical Agriculture (Kenya, Nigeria, Rwanda), African Centre for Gene Technologies (Witwatersrand, south Africa), University of Nairobi Innovation hub, African Biosciences Initiative, the Biosciences Eastern and Central African (BecA) hub, and the International Maize and Wheat Improvement Centre (CIMMYT) facilitate partnerships among universities and research institutions across African countries and can help share resources, knowledge and best practices in genome editing. Regional networks can promote collaborative research projects that address common agricultural issues for young scientists to develop their skills and guarantee their full participation in the field of GEd. African countries should invest in providing mentorship, financial support, and scholarship opportunities (Abkallo et al., 2024).

c When developing and formulating policies and regulations regarding GEd, African countries must foster an atmosphere that is inclusive of young people. This will ensure that youths are well informed about the technology as well as being a part to tackling public scepticism to promote the adoption of GEd (ISAAA, 2022). African governments can inculcate gender intentionality by emphasizing equitable access to resources, funding, and capacity building opportunities. Policies should emphasize equitable access to resources, funding, and capacity-building opportunities for both young men and women. This approach ensures that gender disparities are addressed, allowing for a more diverse group of innovators in the field of genome editing (Ssebunnya, 2023).

d To improve the ability of young scientists to effectively communicate the science of GEd to the public without causing misunderstandings and spreading misinformation, African countries should invest in developing and implementing science communication courses at university level for all students undertaking modern biotechnology courses (AUDA-NEPAD, 2024b).

e African countries should establish incentives/accolades/awards and recognition programmes to honour accomplished young scientists working on potential GEd projects to encourage and inspire more young people to participate in this field of study. Collaborating with established awards such the Royal Society Rising star Africa Prize can provide a platform for recognising early-career researchers making significant contributions to GEd. This prize supports innovative research in physical, mathematical, and engineering sciences and offers funding to enhance their work. They could also provide financial support for young scientists to participate in international competitions or conferences related to genome editing. This exposure can enhance their skills, broaden their networks, and increase visibility for their work.

f African governments should set up networks or platforms, like communities of practice, to facilitate knowledge exchange and encourage collaborations among young scientists working on genome editing research, both inside and outside of their respective countries. For example, the Gene Convene Global

Collaborative focuses on building a community of practice among bioscience professionals in Africa. It organizes short courses and workshops that bring together scientists from various countries to share knowledge and expertise in gene editing technologies (Maeda, 2024). The African Union Development Agency (AUDA-NEPAD) supports various initiatives aimed at enhancing biotechnology research and communication across Africa. Their involvement in developing national communication strategies for genome editing fosters collaboration among scientists, policymakers, and stakeholders (AUDA-NEPAD, 2024a,b).

g To ensure that young scientists play a vital role in promoting genome editing (GEd) for sustainable agriculture and food systems in Africa, governments should expedite the procurement process for laboratory reagents, equipment, and consumables in terms of taxes and levies during procurement. Governments should review and simplify the regulatory frameworks governing the importation of laboratory supplies and equipment. By reducing bureaucratic hurdles, researchers can obtain necessary materials more quickly, facilitating timely project execution. Implementing tax reductions or exemptions on laboratory reagents and equipment can lower costs for research institutions. This financial relief can encourage more institutions to invest in advanced technologies critical for genome editing research. Developing centralized procurement systems for universities and research institutions can enhance efficiency. By consolidating purchasing power, governments can negotiate better prices and ensure that high-quality materials are readily available. Increasing funding allocations specifically designated for the procurement of laboratory supplies will enable research institutions to maintain well-equipped facilities. This investment is essential for supporting young scientists engaged in genome editing projects. Establishing mechanisms to monitor the effectiveness of procurement processes will help identify bottlenecks and areas needing improvement. Regular evaluations can ensure that systems remain responsive to the needs of researchers (Amoah et al., 2024).

h Mandatory inclusion of genome editing technology and other emerging technologies in curricula from high school to university level. For example, in Nairobi, Kenya, Kenyatta University has established programs that integrate genome editing into their agricultural sciences curriculum. The university collaborates with various research institutions to enhance the capacity for GEd research.

i To promote genome editing for sustainable agriculture and food systems in Africa, achieving critical mass is essential to ensure that efforts to adopt and implement GEd technologies have the scale, momentum, and capacity needed to create widespread impact. Critical mass is the minimum threshold of skilled individuals, resources, and infrastructure necessary to drive significant and sustainable change in agriculture.

5 Conclusion

Africa's young people hold the key to its future, and the next generation of scientists will be responsible for the advancement of GEd research in the continent. However, to guarantee the sustainability of Africa's food and agricultural systems, African governments must make a concerted effort to ensure that its young scientists are well-informed, supported, and actively involved in the advancement of GEd technology. This includes creating a conducive environment for young scientists' participation in GEd policies' discussions and formulation, providing capacity building, funding and incentives to motivate and inspire them to be more committed in promoting GEd research and development in the context of agriculture and food systems across the continent. Youth inclusivity in GEd initiatives will empower the next generation of scientists to create agricultural practices that enhance food sovereignty, improve local food systems, and eradicate food insecurity across the continent. By prioritizing the engagement and support of young scientists, we can build a resilient agricultural landscape that secures a prosperous future for all Africans. By doing this, we will undoubtedly create the Africa we want, one in which food insecurity is a thing of the past rather than the present.

Author contributions

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