Rock, JS, et al. 2023. The knowledge politics of genome editing in Africa. *Elem Sci Anth*, 11: 1. DOI: https://doi.org/10.1525/elementa.2022.00143

RESEARCH ARTICLE

# The knowledge politics of genome editing in Africa

Joeva Sean Rock[1,*], Matthew A. Schnurr[2], Ann Kingiri[3], Adrian Ely[4], Dominic Glover[5], Glenn Davis Stone[6], and Klara Fischer[7]

How is the promise of crop genome editing viewed by scientists working with or aspiring to work with the technology, by development experts seeking to mold public perceptions and policy attitudes toward genome editing, and by donors that provide funds for genome-editing research for agricultural applications in sub-Saharan Africa? In this article, we present data from interviews with these stakeholders to shed light on their aspirations, concerns, and expectations. Previous scholarship on genome editing in relation to African agriculture has focused on the technical capabilities of genome editing techniques and surveys of current research and development activities in this field. This article contextualizes and reflects critically on expectations that genome editing can or will deliver benefits for African scientists and farmers. The interviews reveal excitement around genome editing and anticipation for what it could achieve, but also a sober realism and frustration regarding the political-economic hurdles that constrain African scientists and research institutions and the generation of public goods for African farmers and societies. These insights, we show, challenge extant narratives related to genome editing and accessibility. As such, we center and interrogate the politics of knowledge surrounding the emergence of genome editing in Africa.

**Keywords:** GMO, Gene editing, Biotechnology, Agricultural development, Knowledge politics, Africa

Over the past decade, the advent of CRISPR and other tools of genome editing[1] has been heralded by some as a "revolutionary" technology. This particular narrative presents the technology as cheap, easy to use, and able to circumvent supposedly restrictive regulatory regimes (Komen et al., 2020; Qaim, 2020, p. 137; Abdallah et al., 2022). It parrots the laudatory promises that accompanied previous generations of heavily hyped plant breeding technologies, including genetic modification (GM) (Glover, 2010; Rock et al., 2023).[2] However, such historical links—and lessons that might be learned from them—remain largely overlooked within accounts celebrating genome editing's transformative potential for plant breeding. Instead, commentators in both the academic literature and popular presses tend to repeat optimistic headlines about genome editing's ability to "feed the world," echoing previous attempts to elevate a new breeding technology as a silver bullet solution to increase global agricultural productivity (De Amstalden, 2023; Doudna, 2023). These narratives and their contestations bely a knowledge politics surrounding genome editing that this article aims to explore.

Africa features prominently within these promissory narratives. Anticipatory accounts have focused on the potential agricultural applications for genome editing, including the targeting of African staple crops and the uptake of genome editing within public breeding programs (Abugu, 2021; Karavolias et al., 2021a). The latter expectation—that genome editing, unlike GM, will be widely available to smaller labs and scientists in the Global South due to supposed lower costs—animates much of this literature. Others have positioned the continent as ideally suited to benefit from these technologies: "the African continent is *uniquely poised* to benefit from advances in gene editing technology" because it was "largely overlooked by the Green Revolution that delivered higher yielding grain crop varieties to Asia and Central/South America" (Karavolias et al., 2021b, para. 6,

1. We define genome editing as "a technique of genetic engineering that involves the alteration of an organism's genetic structure by adding, deleting, changing, or replacing individual nucleotides or sequences of DNA" (Glover et al., 2020, p. 2).

2. This narrative has a long history. As historian Helen Anne Curry (2016) has written, since the early 20th century, successive new technologies in plant breeding have been described for their speed and "revolutionary" potential.

[1] Department of Politics and International Studies, University of Cambridge, Cambridge, UK
[2] Department of International Development Studies, Dalhousie University, Halifax, Canada
[3] African Centre for Technology Studies, Nairobi, Kenya
[4] Science Policy Research Unit, University of Sussex, Brighton, UK
[5] Institute of Development Studies, Brighton, UK
[6] Sweet Briar College, Sweet Briar, VA, USA
[7] Department of Urban and Rural Development, Swedish University of Agricultural Sciences, Uppsala, Sweden

* Corresponding author:
Email: jr872@cam.ac.uk

emphasis added). This portrayal of Africa having missed out on the original Green Revolution, thus requiring a surge in innovation and investment into new breeding technologies, has been the defining feature of the continent's agricultural development over the past 20 years (Moseley et al., 2015; Bergius and Buseth, 2019).

Claims of Africa being "uniquely poised to benefit" from this latest breeding technology are worth scrutinizing. This article shines a light on the opinions, realities, and goals of those working with genome editing techniques on the African continent to better understand the knowledge politics undergirding this new wave of technological optimism. The perspectives of scientists who have embraced genome editing, those of donors who are funding such work, and of biotechnology policy experts working to shape public and political perceptions of the technology, matter in assessing (if and) how the technology is being both accessed and deployed (Middelveld and Macnaghten, 2021). Thus, in this article we ask: *how do stakeholders view the genome editing of crops and its agricultural applications in sub-Saharan Africa?*

In what follows, we present data from interviews with 13 scientists, donors, and biotechnology policy experts working in the fields of agricultural development, plant breeding, and biotechnology in sub-Saharan Africa. These interviews, undertaken on Zoom during the height of the COVID-19 pandemic, shed light on how knowledge politics might shape the trajectory of a potentially powerful tool in an uncertain time. Overall, while most of our interlocutors were enthused about the technological potential genome editing might offer, many also spoke to structural challenges to accessing the technology and housing it within African research institutions. Following these interlocutors, this article approaches genome editing not as an exceptional technology but rather as another tool, entangled within social, political, economic, and historical webs.

The article proceeds as follows. First, we explore the literature surrounding the knowledge politics of agricultural research to situate the nascent but growing social science scholarship on genome editing and its agricultural applications. Immediately following, we discuss the methods that drive our analysis. Then, we present an overview of the nascent experimental pipeline of genome-edited crops and assess 3 themes that arose from our interviews: the question of regulation, the importance of infrastructure, and the perils of simplistic narratives. We conclude with thoughts on the challenges facing those wishing to access and deploy genome editing.

## The knowledge politics of genome editing

The shaping of new biotechnologies has been analyzed through the lenses of expectations (Hedgecoe and Martin, 2003; Tutton, 2011) and imaginaries (Jasanoff, 2004; Bain et al., 2020)—the identification of which help us move beyond simple interest-based approaches in understanding emergence. In this article, we focus our attention on the *narratives* adopted by different constituencies in the ways they describe expectations and imaginaries associated with gene editing. Narratives have been used in the analysis of politics and policy for decades (Roe, 1994) and have been described as "simple stories with beginnings defining the problem, middles elaborating its consequences and ends outlining the solutions" (Leach et al., 2010, p. 45). In the case of seeds in Africa, for example, an example narrative might be "growing food deficits require massive boosts to agricultural productivity and only GM crops will provide the answer" (Leach et al., 2010). By mapping some of the extant narratives more specifically related to genome editing and questioning their assumptions based on interview data, we interrogate the politics of knowledge (Leach et al., 2010, p. 75) surrounding the emergence of genome editing in Africa.

Indeed, expectations regarding genome editing's application on the African continent have multiplied over the past decade. This literature, largely anticipatory in nature, enumerates several potential pathways for genome editing, including tackling invasive pests and diseases (Bart and Taylor, 2017; Ogaugwu et al., 2019; Bellis et al., 2020; Abugu, 2021; Tripathi et al., 2022), reinvigorating public breeding programs (Wartha and Lorenz, 2021), enhancing food and nutrition security for poor farmers (Mudziwapasi et al., 2018; Karavolias et al., 2021a), and "revolutioniz[ing] crop improvement" (Travella et al., 2019; Komen et al., 2020). Such pathways, proponents argue, are contingent upon biosafety regulations that govern genome-edited crops differently than GM crops (Nang'ayo et al., 2014; Pixley et al., 2019, p. 176), in the hope that decreasing regulatory costs allow smaller labs and firms to access the technology (Lloyd et al., 2021; Paarlberg and Smyth, 2023).

Africa has long been important in imaginaries around agricultural biotechnology, both as a location for technological advancement and as a narrative device for conjuring what the technology can (or cannot) achieve. Academics, officials, and biotech firms alike argued that GM crops would "feed the world" (Borlaug, 2000) and enable Africa to "leapfrog into more sustainable methods of agricultural production" (Juma, 2015, p. 64). These techno-optimist assessments are rooted in a narrative that understands low productivity rates in Africa as being a function of outmoded technology, tools, and agricultural knowledge (Logan, 2020). This narrative has a long historical arc: it emerged from and was codified during colonial rule and persisted within postcolonial regimes, portraying Africa and African farmers as apart from the world, with little to offer, and in need of "improvement" (Rodney, 1982; Yapa, 1993; Canfield, 2022).

Narratives of technologies and geographies are, in one regard, a matter of *knowledge politics*, that is, how "individuals and groups selectively generate and/or use knowledge to establish, maintain or enhance their vested interests" (Andersson and Sumberg, 2017, p. 6). Different from "technicist conception[s] of technology," wherein "technologies are thought to have fixed functional characteristics that produce predictable effects" (Glover et al., 2017, p. 15), critical analyses of knowledge politics are rooted in the assumption that ideas, aspirations, and biases shape decision-making around technologies and research programs (Andersson and Sumberg, 2017, p. 7). In other words, technology is understood not as a static package delivered to end users but rather as something that is molded by socioeconomic conditions, prevailing ideologies, geopolitics, and imaginaries (Winner, 1980; Akullo et al., 2018; Middelveld and Macnaghten, 2021).

The politics of knowledge—especially that related to technology and development—has been of great focus within science and technology studies, critical agrarian studies, anthropology, and beyond. For example, Middelveld and Macnaghten (2021) show how different sociotechnical imaginaries of Dutch scientists are shaping conversations, research, and governance around the genome editing of livestock in the Netherlands. Andersson and Sumberg (2017) draw attention to how larger political-economic forces shape agricultural research programs. They argue, for example, that the neoliberal turn of the 1980s profoundly affected agronomy programs, in that it divorced agronomy from the state, and moved agronomic knowledge, projects, and outputs away from the public domain. Writing on what he terms the “ideology of innovation,” Canfield suggests that the forces driving sustainable intensification on the continent are deeply embedded in the neoliberal project of “reframe[ing] political problems as market opportunities” which are in turn used to “catalyze technological development” and “justify the dispossession of peasant’s and Indigenous people’s knowledge” (2022, p. 2, 4). Others have similarly highlighted the ways in which narratives surrounding tools of development mask historical and structural inequities and thus serve to decontextualize and depoliticize complex structural challenges such as poverty (Benton, 2015; Pierre, 2020).

Questions around knowledge politics animate the social scientific scholarship on genome editing. Some critical social scientists have argued that promoters “scientize” narratives around genome editing—for instance, emphasizing (supposed) efficiency—which allows them to circumvent discussing stickier social and regulatory issues (Helliwell et al., 2019, p. 781; Mueller and Flachs, 2022). Others have zeroed in on the key battle ground of regulation as countries debate whether to regulate genome-edited crops through process- or product-based approaches (Ely et al., 2022). Kuzma (2018, p. 81) argues that some stakeholders “[play] the name game,” using terms that decouple the technology from GM, in hopes of avoiding similar regulatory regimes, which they contend served to stifle the uptake of GM crops. Others have called for regulators to move beyond thresholds of what is “safe enough,” and toward regulations that foreground transparent public debate and considerations of biodiversity, farmers’ rights, and other socioeconomic concerns (Kjeldaas et al., 2022).

Social scientific critiques of genome editing have also problematized the narrative of “democratization”—the expectation that genome editing will be more accessible than its technological predecessors (Ricroch, 2019). Writing on the large pool of genome editing start-ups, Clapp and Ruder (2020) argue that de-centralizing power in the field is possible, but not guaranteed, as the likelihood of industry consolidation always looms. The initial biotechnology rush of the 1980s, after all, was marked by several small start-ups and firms, which were gradually consolidated into larger firms (Boyd, 2013). Moreover, through interviews with genome editing experts and scientists, Montenegro de Wit points to how, despite narratives of democratic use, “sharp lay/expert boundaries persist, and overlapping accesses to knowledge networks, funding, and infrastructure mediate the difference between access to a tool and the capacity to use it” (2020, p. 24).

Other critical assessments highlight how innovation “systems”—financial and material resources, such as the funding and lab equipment, skills, infrastructures, and policies—shape the accessibility and development of agricultural technologies (Hall, 2005). Those concerned with plant breeding and agricultural development on the African continent expose the degree to which African public research organizations are broadly underfunded and reliant on donor support (Roseboom and Flaharety, 2016; Hall and Dorai, 2020). This is especially relative to institutes within the Consultative Group for International Agricultural Research (CGIAR), an international agricultural research system that focuses on agricultural development in the Global South. The historical divergence of these 2 systems—national public research organizations versus international research centers—is key for understanding the knowledge politics of plant breeding on the African continent: while both systems grew out of colonial scientific networks, donors began to view the CGIAR as a way to centralize and direct research priorities as African nations gained independence in the 1960s and 1970s, playing a central role in the “post-colonial transition to a new national order” (Byerlee and Lyman, 2020, p. 14). As a result, African public research organizations remain largely underfunded and undersupported in terms of infrastructure. One consequence of this structural inequity has been the growth of public–private partnerships (PPPs) between African research organizations and private firms. While some consider PPPs to be a key vehicle for bridging technical and funding gaps between the public and private sector, and allowing public sector researchers to access new technologies (Spielman et al., 2010; Spielman and Zambrano, 2013), the empirical record has shown that PPPs are often marked by an imbalance of power between collaborators (Schurman, 2016) and have struggled to successfully develop and commercialize GM crops for African farmers (Schnurr, 2019).

Finally, social scientific assessments of genome editing have challenged simplistic portrayals of the technology’s efficiency and ability to meet the diverse needs of smallholder farmers. Shah et al. (2021) showcase how scientific debates regarding genome editing reveal disagreement within the scientific community over the technology’s preciseness, and argue that these important disagreements are obfuscated by actors circulating narratives about genome editing’s supposed superiority and accessibility. A recent review by Schnurr et al. (2022) underlines the complexity of genome editing for abiotic stresses such as drought tolerance, and therefore challenges the representation of genome editing as a more accessible form of plant breeding. This narrative of accessibility was empirically assessed by Beumer and de Roij (2023), who reviewed 30 research projects using genome editing to breed crops and traits explicitly for smallholder farmers.

They found that the number of initiatives—when compared to genome editing of plants globally—is relatively small, and that most initiatives were limited in their inclusion of farmers' knowledge, needs, and interests as part of the innovating process.

Taken as a whole, a review of social science assessments of genome editing reveal contentious knowledge politics at play. Regulation, infrastructure, and the complexities of technological innovation loom large. These themes also featured prominently within our interviews, to which we now turn.

## Methodology

To understand how stakeholders view the genome editing of crops and its applications for agricultural development, we sought out interviews with scientists, donors, and biotechnology policy experts working in the fields of agricultural development, plant breeding, and biotechnology in sub-Saharan Africa. We identified potential interlocutors by generating a list of authors of relevant publications, scientists featured in news articles on the topic, and individuals known through our respective professional networks.

Of the 32 individuals we approached, 13 agreed to be interviewed. This relatively small respondent pool reflects the nature of the small and emerging field of genome editing in Africa. The group, comprising 10 men and 3 women, included 8 scientists, 3 biotechnology policy experts, 1 university student, and 1 donor. Geographically, 6 were based in institutions in East Africa, 4 in West Africa, and 3 in the Americas. The scientists worked at a mix of research institutions, universities, and the CGIAR. The biotechnology policy experts worked at organizations with various mandates, including developing political and technical infrastructure for biotechnology projects and building public support for the technology. Given the small number of people working in this field, we only provide broad demographic details, and we attribute quotes with generic labels to ensure anonymity (e.g., "CGIAR Scientist 1").

Due to the COVID-19 pandemic, all interviews were conducted via Zoom in the spring of 2021. We asked open-ended questions such as: what possibilities or advantages does genome editing offer African agriculture? What are some of the potential challenges facing the adoption/embrace of genome editing at the research level? What sorts of lessons, if any, can we draw from the experience of GM crops? With focus on the country of region of the respondent, what are some of the biggest challenges and opportunities for agricultural development and ensuring food security?

After transcribing the interviews, we analyzed them in NVivo, using an iterative approach that allowed for successive rounds of inductive coding. This process allowed us to zero in on the key themes, patterns, and divergences that emerged across the interviews (Thomas, 2006). Out of this process, we identified 3 key themes: the question of regulation, the importance of infrastructure, and the perils of simplistic narratives. We first present the interview evidence related to each of these themes, identify the (in)congruencies across respondents, and then analyze each theme with reference to the narratives in the literature outlined above.

Finally, we conducted a desk review to identify crop breeding projects that are using genome editing in their work. The desk review included surveying peer reviewed literature, project websites, and press releases. We identified the crops, traits, and actors that make up these projects, which we combined with our interviews and literature review to assess the current state of the experimental pipeline.

## Genome editing in Africa

How is genome editing being used to develop crops for African farmers? A high-level view of the nascent pipeline provides some broad oversight into how the technology is being used (see **Table 1**). First, much of the work is taking place either directly within, or in partnership with, CGIAR institutes and African institutions, and much of this work is reliant on partnerships. In some cases, these partnerships include a private-sector actor, but in others, they do not. The projects focus on a variety of crops—including banana, cassava, cocoa, maize, millet, rice, sorghum, and sweet potato—and several traits, including diseases resistance and drought tolerance.

However, a list of current applications is only one part of the wider story. With this broad framing in mind, we now turn to interviews with our interlocutors, whose expertise provides insight into how the technology is—and isn't—being rolled out in real time.

### *"Not really GM": On the question of regulation*

For those we interviewed, one of genome editing's strongest assets is its potential to rethink policy around biotechnology. Interlocutors were adamant that biosafety regimes across the continent remain too stringent and hamper innovation. "Africa's experience with [GM] has been very bad," said one scientist at CGIAR, "you see a lot of people kicking against it . . . that is why up to now there are many countries in Africa that do not even have regulation . . . And so, now that genome-editing has come in, it's potentially good and different from GM, so what we have to do is, you have to do a lot of sensitization . . . Otherwise, we still have to go down the same road of GM" (CGIAR Scientist 4, February 6, 2021). Others we spoke with echoed this point. "There is still a stigma of the transgenics," said one scientist at CGIAR, "so there is also the complexity of regulations. Especially in certain parts of Africa" (CGIAR Scientist 6, March 16, 2021). Another scientist at CGIAR said, "You have the biosafety regulation institution in our places. In some cases, they behave like people who are there to stop the technology to be adopted, instead of being the people who are just assessing and making sure that all the procedures are well followed" (CGIAR Scientist 3, February 4, 2021).

Many of our interlocutors expressed hope that African governments would regulate genome-edited products differently than their GM counterparts. An official involved with regulatory design shed light on the type of regulations their employer was advocating for: "the approach that the African nations want to use is the science-based

**Table 1. Select research and development pipeline of genome edited crops targeted for Africa**

| Crop | Trait | Lead Research Institution | Partnering Research Institutions |
|---|---|---|---|
| Banana | Banana streak virus | The International Institute of Tropical Agriculture (Kenya) | University of California-Davis |
| Cassava | Virus resistance[a] | Donald Danforth Plant Science Centre (DDPSC) (USA) | Corteva Agriscience; National Crops Resources Institute (Uganda) |
| Cassava | Cassava bacterial blight disease | National Root Crops Research Institute (Nigeria) | DDPSC; Bill & Melinda Gates Foundation (BMGF; funding); National Science Foundation (funding) |
| Cassava | Cyanide reduction | Innovative Genomics Institute (University of California-Berkeley, USA) | DDPSC |
| Cocoa | Swollen shoot virus | Penn State University (USA) | National Science Foundation (funding); U.S. Department of Agriculture (USDA)—National Institute of Food and Agriculture |
| Maize | Maize lethal necrosis | International Maize and Wheat Improvement Centre (CIMMYT) (Mexico) | Corteva Agriscience; Kenya Agricultural and Livestock Research Organization (KALRO); Seed Trade Assoc. of Kenya; USDA-Agricultural Research Service; BMGF (funding) |
| Maize | Drought tolerance | VIB-Ugent Centre for Plant Systems Biology (Belgium) | Kenyatta University |
| Millet | Reducing rancidity[b] | International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (India) | Corteva Agriscience |
| Rice | Yellow mottle virus resistant[c] | National Agricultural Research Organization (Uganda) | National Crops Resources Research Institute (NaCRRI)-Namulonge Campus |
| | Bacterial leaf blight | Heinrich-Heine-University (Germany) | University of Florida; University of Missouri; International Rice Research Institute; The International Center for Tropical Agriculture; Research Institute for Development; Indian Council of Agricultural Research; DDPSC; BMGF (funding) |
| Sorghum | Striga-resistant | The International Service for the Acquisition of Agri-biotech Applications (ISAAA) AfriCenter | Kenyatta University, Addis Ababa University, U.S. Agency for International Development (funding) |
| Sorghum | Striga-resistant | Penn State University (USA) | Corteva Agriscience; Kansas State University; Kenyatta University; ICRISAT; Royal Botanic Gardens Kew; Sorbonne Université; University of Texas; Uppsala University; University of Virginia; Advanced Research Projects Agency-Energy (funding); National Science Foundation (funding); U.S. Department of Energy (funding) |
| Sweet potato | Vitamin A[d] | University of Cape Coast (Ghana) | North Carolina State University |

[a]While virus resistance is the project's targeted trait, genome editing is being initially used to develop a proof of concept by targeting flowering (Interview, February 5, 2021).

[b]This work was in partnership with ICRISAT and Corteva Agrisciences. The research was undertaken in part by 2 PhD candidates who held a 10-week internship at Corteva (International Crops Research Institute for the Semi-Arid Tropics, 2019).

[c]Scheduled to begin at a later date.

[d]This research program originally began at North Carolina State University but is currently on hold after the PhD student undertaking the research switched institutions (Gakpo, 2021).

*Sources:* Banana: Maina (2018); International Pest Control (2019); International Service for the Acquisition of Agri-Biotech Applications (2021); Cassava: Murdock (2020); Okwuonu (2021); Cocoa: Gill (2018); Maize: Maina (2018); International Service for the Acquisition of Agri-Biotech Applications (2021); Millet: International Crops Research Institute for the Semi-Arid Tropics (2019); Rice: AgNews (2020); International Service for the Acquisition of Agri-Biotech Applications (2021); Sorgham: Maina (2018); Penn State (2020); U.S. Agency for International Development (2022).

approach: if the product is same as the conventional, it should be regulated as conventional. If the product is the same as (a genetically modified organism [GMO]), it should be [treated] as GMO. If the product starts off as GMO and then ends up as non-GMO, once you confirm that the GMO part has been removed, it should be regulated as conventional product" (Biotechnology Policy Expert 1, February 12, 2021). One scientist we interviewed considered such a regulatory approach a "landmark":

> *I think most important is that gene editing appears to become one of those biotechnologies that will not be as regulated as genetic engineering as we knew it before . . . I think that's landmark for gene technology because a lot of resistance to conventional genetic engineering has caused delays and perhaps halted what many products would have been released by now.* (Research Institute Scientist 2, March 16, 2021)

CGIAR scientists suggested that less restrictive regulatory processes would free up resources for scientists to work on plants and traits relevant to smallholder farmers. "The way I understand [genome editing]," said one scientist at CGIAR, "[is] the fact that it's not really considered GM as such[;] It's just going to provide great opportunities" (CGIAR Scientist 5, March 11, 2021). Another scientist at CGIAR echoed this sentiment while highlighting the potentially reduced cost of producing genome edited crops (in comparison to GM):

> *[One of the] really huge advantages of gene editing and in the prospects of Africa [is] the fact that gene editing is relatively speaking, extremely inexpensive . . . It's pretty simple. And what this allows is that you . . . can afford to use it for products that aren't the big moneymakers, that aren't going to get the attention of the big seed companies because there isn't money in it for them . . . [For example], there's a lot of crops that have serious disease problems for which gene editing might provide very effective solutions quite inexpensively, and therefore really be of great benefits to farmers that aren't served by large companies.* (CGIAR Scientist 2, January 22, 2021)

The scientist continued, mentioning several crops they thought could benefit from genome editing, including cassava, yams, and teff (Scientist, CGIAR, 22 January 2021). A second scientist listed egusi melon, cocoyam, and taro as crops ideally suited to genome editing (CGIAR Scientist 4, February 6, 2021).

While many interlocutors expressed excitement about the scientific possibilities of genome editing, this optimism was tempered by sober reflections on infrastructural realities and a desire to not "oversell" the technology. Many also spoke of structural inequities through the lens of infrastructure, and the very real material and financial struggles they face in their labs. We turn to those considerations in the next section.

### *"Research is expensive": On the importance of infrastructure*

The next theme that emerged among our interlocutors related to infrastructure. Infrastructure here refers to the in-country facilities that enable scientists to do their job, which could include lab access and supplies, electricity and Internet, and genetic material, alongside funding, a key resource in obtaining (and retaining) infrastructural resources. Taken together, questions of infrastructure are questions of accessibility, and speak to the narrative of genome editing being cheap, easy, and readily available.

While interlocutors were in broad agreement that genome editing was likely to cost less than GM, many pointed out that cost reduction was not necessarily synonymous with accessibility. Said one scientist at CGIAR, "As a powerful technology, many people talk about- 'Oh, you can do it in your garage'. Well, it's not that easy. Conceptually, it's pretty simple. But, you know, as you start actually doing it, you realize that this is not that easy. But nonetheless, it's pretty inexpensive" (CGIAR Scientist 2, January 22, 2021). Another scientist at CGIAR emphasized that funding varied across institutions within Africa: "It is only in these international institutions [CGIAR] that can do this work . . . I'm not sure [national] institutions would not see these facilities because funding is limited" (CGIAR Scientist 4, February 6, 2021). Here, the scientist pointed to a lack of infrastructure at public universities and research institutes relative to the CGIAR centers. While some of our CGIAR interlocutors similarly raised issues around funding, overall, they seemed more confident in their ability to capitalize on genome editing given current resources:

> *We don't have many challenges because genome editing doesn't require anything extra. You know, if you have the laboratory facilities that you are using anyways for transgenic [modification], with similar facilities we can do gene editing. So, apart from funding, . . . I don't see any big challenge.* (CGIAR Scientist 1, January 21, 2021)

It was a different story for interlocutors outside the CGIAR system. One scientist based at a national research institute emphasized that many public institutions employ scientists skilled in genome editing, but that a lack of funding inhibits their ability to purchase the tools and materials necessary to complete the breeding process:

> *the pipeline for doing that kind of work is in place but what is a bit limited is finding additional money to implement on your own research ideas. Compared to America where there are many funding agencies, we have the opposite here. They're very limited and we also find ourselves applying for the same grants as other nationals, . . . and because of that our chances of succeeding are limited. But we keep trying.* (Research Institute Scientist 1, February 5, 2021)

An interlocutor at a public university echoed this point. This individual had recently returned home after spending a few years abroad working on genome editing. They affirmed that they were continuing their work at their new institution, citing the common narrative that genome editing requires few financial or material resources: "for ... genome editing you don't really need much. You don't need super sophisticated materials. We have the basic tissue culture laboratory and some of the people we need" (University Scientist, February 25, 2021).

But, as they continued, the scientist began to enumerate several challenges: "Most of the things we would be needing, we have to order from the biotech companies ... For supplies, like enzymes, and you know so many of the supplies, we will have to order them." Ordering supplies, the scientist explained, not only required funds but also time and patience: "You [might] have the money, but when the ordering process is so difficult. Cumbersome." They continued, listing the work that goes into clearing the supplies at customs, paying import duties, and so on. Once supplies are obtained and the work can commence, the scientist still faced issues with a lack of lab equipment: "And then also we will be doing a lot of sequencing. [There's] a lot of sequencing that we cannot do it here. Once we get our DNA, we can send the samples to the partner companies to do the sequencing for us." Later in the interview the scientist concluded, "research is expensive" (University Scientist, February 25, 2021).

The infrastructural constraints that the university scientist spoke to were vast: ordering and paying for supplies, navigating customs and import taxes, collaborating with an outside lab to sequence DNA, and so on. Overcoming these constraints was not only expensive but also required significant outsourcing: neither supplies nor sequencing could be obtained in house. The differing perspectives offered by those scientists within and outside the CGIAR space underscores the trenchant divide between plant breeders based at international organizations and those based at national-level research organizations whose relative lack of infrastructure and funding make such ambitious experimental programs feel largely out of reach.

#### *"Maybe ... overselling it": On the perils of simplistic narratives*

The hope that genome-edited products would not be considered GMOs—either by regulators or by the public—that remains pronounced within the literature was echoed by many interlocutors. This designation is as much discursive as it is technical. Discursively, creating distance between genome editing and GM was seen to be a way to move past a technology that has generated immense public and political scrutiny. In other words, cementing a linguistic distinction was a way to generate more public support. Said one CGIAR scientist:

> *There is a lot to learn from GM when moving forward. It is more related to communication I will say. So, you know start with early communication, ... and use very simple way of explaining the technology in a clear way. Then is public awareness, so people don't fear the new technology ... To build the confidence in the public I think that communication is the key.* (CGIAR Scientist 1, January 21, 2021)

Describing differences between GM and genome editing was also a way, some believed, to generate more favorable regulatory models (explored above in the section entitled "On the Question of Regulation"). Here, some interlocutors—mainly those who worked outside public institutions—again referenced the narrative of genome editing as easier, cheaper, and more accessible than GM. Said one interlocutor: "Genetic modification is already phasing out now, because gene editing is less cumbersome, is more precise, ... and doesn't take so much money [and] doesn't take so much time" (Biotechnology Policy Expert 2, February 19, 2021).

However, some interlocutors worried that such messaging oversimplified a complex field and could be counter-productive for convincing members of the public of its value. One topic that interlocutors raised was the narrative—and technical designation—of genome editing as a significant departure from GM. At least one interlocutor called this narrative "disappointing" and "confusing":

> *it is disappointing because many people, maybe because of vested interests, want to portray genome editing as the same as conventional [breeding]. And that is causing a lot of confusion. It is true that because of the high expenses in GMO, most of what will come up as genome editing will eventually be the same as conventional. But I think the precise truth is that some of the products will come out identical as conventional from the beginning, some of the products will have a component of GMO at some stage, then that GMO part is removed.* (Biotechnology Policy Expert 1, February 12, 2021)

We asked our interlocutors what lessons, if any, they thought were relevant from the previous generation of GM. One scientist at CGIAR worried that portraying genome editing as being easy to implement parroted previous narratives of GM as being a quick and easy sell. The scientist worried that deploying such a narrative around genome editing might be "overselling it":

> *Probably a big mistake of the early days of transgenic technologies was assuming that society would embrace these things. As scientists, ... there was so much excitement about what transgenic would be able to achieve. That, you know, scientists look at this, "Wow, we're going to be heroes, everyone's going to love us for this, ... who could possibly be against this?". I think this [was] sort of naïve ... And then maybe the other thing was overselling it. I mean, and this is also true of gene*

> *editing. A lot of really important traits in any crop, such as drought tolerance or heat tolerance or certainly yield, are influenced by many, many genes . . . So, you're not going to triple yields with a transgenic, or with the gene edited product . . . So that, those are some of the mistakes that we made with transgenics and I don't know if it's rescuable.* (CGIAR Scientist 2, January 22, 2021)

The comments from both the Biotechnology Policy Expert 1 and CGIAR Scientist 2 come down to the question of building public trust. Both interlocutors identified several variables that might dampen public trust and acceptance: misrepresenting the type of biotechnologies used to develop a plant; glossing over issues of safety and regulation; and promising mass access. One interlocutor noted that these considerations were not unique to the African continent: "In Africa, gene editing is still so new, *[like] everywhere else*" (Research Institute Scientist 2, March 16, 2021, emphasis added).

However, one scientist at CGIAR mentioned an additional factor that was more geographically, and historically, specific: "it will help to increase the trust in the technologies if people know that it's developed locally, by a fellow citizen" (CGIAR Scientist 3, February 4, 2021). They continued, drawing a connection to the COVID-19 pandemic and vaccine deployment:

> *I don't know if you are aware of the discussion when people were in the phase of development of the vaccine for COVID-19? There were some people that were thinking of doing the trials in Africa, and there was a lot of discussion. People said "no, no, we are not going to be guinea pigs for you guys. Develop your vaccine, try it on your own people, don't bring it here". People have the feeling . . . there are many people in our places that have the feeling that the Western guys they are plotting something . . . And this is very difficult to change. So, then, if you want to build trust, then you have to invest in . . . the continent. Otherwise, it will be very difficult.* (CGIAR Scientist 3, February 4, 2021)

Here, the interlocutor is speaking to specific historical and political-economic contexts through which they believe individuals may judge genome editing as citizens or consumers. In the next section, we discuss how historical contexts, structural inequalities, and ideas about technological advancement provide essential insights into the future of genome editing in Africa. These insights lead us to question narratives around the "revolutionary" potential of genome editing and to interrogate the knowledge politics at play across the continent's diverse contexts of research and innovation.

## Discussion

Across our interviews, respondents expressed a range of ideas regarding the possibilities and realities of genome editing. Most of the scientists we interviewed expressed enthusiasm about the technology's potential, one that echoes the narrative that dominates within popular and academic sources. But there was a distinct difference between interlocutors within the CGIAR system, and those outside of it. In comparing the transcripts from the scientists at African universities or national research institutions—who spoke of cumbersome processes of ordering supplies, sending materials for sequencing, and obtaining funding—to that of the CGIAR scientists ("apart from funding, I don't see any big challenge"), a particular and important tension comes to light: that of the capacities enjoyed by the CGIAR centers versus national research institutions. This division reflects a half decade of divestment from national research institutions, by both governments and donors, even though repeated reviews have recommended devolving and decentralizing CGIAR's role in plant breeding to national programs who are better positioned to lead such experimental programs (Byerlee and Lynam, 2020; McIntire, n.d.).

While some scholars are optimistic about the ability of small labs to benefit from genome editing (e.g., Qaim, 2020), interlocutors outside of the CGIAR system worried about their ability to access the funding and tools they would need in order to lead their own genome editing projects. Here, concern extends beyond simply whether scientists possess the skills to utilize new agricultural technologies, but rather, whether the systems exist that enable them to *apply* them (Hall, 2005).

This divide in access is evident within a review of current projects that are using genome editing—either as a main instrument or a single tool within a larger suite—to address diseases, pests, and staple crops. **Table 1** reveals several national institutions involved in genome editing projects. However, few serve as the lead research institution on projects; in fact, the entirety of this work is being undertaken as partnerships. To be sure, partnerships are a common component of agricultural research, especially within the portfolio of biotechnologies. But partnerships also raise important questions around availability and accessibility of technology. In other words, if a technology is only accessible through partnering with another entity—an arrangement that inevitably involves negotiations among partners endowed with different capabilities and distinct interests—how "accessible" is it?

This unmasks another dimension of the knowledge politics surrounding genome editing. The ability of scientists, whether within the CGIAR or national research institutions, to work on crops of their choosing is highly dependent on their access to materials and technologies. Partnerships are one way to access these, but they can be complicated and messy, and are usually marked by asymmetrical power relations (Beumer and de Roij, 2023). Public–private partnerships also have a mixed track record when it comes to the delivery of public goods in the realm of agricultural biotechnology development on the African continent (Schnurr, 2019).

An important aspect of the power imbalance among partners stems from patents, an aspect of research infrastructure that was not necessarily raised by our respondents, but which looms large. Both public institutions (such as University of California-Berkeley) and private-sector firms (such as Corteva) have rushed to claim genome editing patents (Egelie et al., 2016; Jefferson et al., 2021). While some of these entities are licensing their patented technology for noncommercial use (van der Oost and Fresco, 2021), patenting still serves as a method of enclosure (Ajates, 2022; Canfield, 2022). Access to patent-protected techniques and materials is at the discretion of the patent owner, and so the rapid patenting of the sector raises doubts around future accessibility by smaller labs (Kock, 2021).

Through interviews and review of the nascent experimental pipeline, an image begins to emerge of a new technology unfolding unevenly across the African continent. Despite the buoyant public narratives that surround genome editing, there are currently few instances of it being applied to crops targeted for African farmers. This tracks with recent findings from Beumer and de Roij, who argue that globally, "the use of gene editing for smallholder farmers is emerging slowly at best" (2023, p. 1). In some ways, this slow emergence and uneven unfolding reflect larger structural, historic inequities. Addressing this is not simply a matter of building knowledge and labor capacities (though those do play an important role) but also of directing funding toward the building and maintenance of infrastructure in national research institutions, universities, and other domestic entities.

It is perhaps for these reasons, and more, that many of our interlocutors spoke to the danger of simplistic narratives, and how their use might harm efforts to build trust and understanding among the public. For example, Biotechnology Policy Expert 1 shared that it was "disappointing" that some sought to "portray genome editing as the same as conventional [breeding]." This insight echoes Kuzma's argument: that using overly simplistic phrases or narratives can be perceived as "dishonest" and "lacking integrity" by the public (2018, p. 81). CGIAR Scientist 3 spoke to the need for transparent discussions around genome editing, and referenced COVID-19 vaccine trials and people's fear of being "guinea pigs" (see above) to make their point. As Flint (2020, p. 130) has shown, "historical antecedents of ... medical experimentation, [and] continued structural inequalities" live on and inform views on things like vaccines. Historical precedent and structural injustices also shape how some view biotechnology (Rock, 2022).

In sum, our conversations with stakeholders actively invested in genome editing in Africa reveal the myriad challenges they face on the ground and expose some of the more trenchant obstacles—in terms of access, logistics, and control—that stakeholders perceive as potential barriers to achieving genome editing's triumphalist potential in Africa. The knowledge politics that underlay the rollout of this new technology mirror that of previous generations of agricultural technologies: a multistakeholder program that affords preferential access to those scientists within multinational bodies (like CGIAR) relative to those housed within national organs. At the same time, scientists across different institutions expressed considerable interest and expertise in using genome editing tools. Narrowing this gap between interest and accessibility will be crucial for achieving genome editing's transformative potential.

## Conclusion

In this article, we interviewed scientists, donors, and biotechnology policy experts to answer the question: *how do stakeholders view the genome editing of crops and its agricultural applications in sub-Saharan Africa?* Some of our findings support that which is already established in the social scientific scholarship, mainly that practitioners are by and large optimistic about the potential applications of genome editing, and that many hope—and are working toward—political regimes that regulate genome-edited products as distinct than genetically modified ones.

However, our interviews provide a more sober, empirical assessment to a narrative that is positively buoyant in its expectations for genome editing. As explored here, the dominant narrative that positions genome editing as being more accessible than previous biotechnologies overlooks the vast complexities of plant breeding and genome editing, and the choices scientists must make when developing a research and development strategy: when using genome editing on a crop for the first time, scientists must first develop a proof of concept prior to executing on their actual targets; labs must be well-equipped with supplies and tools; projects must be well-funded to pay for both materials and labor; desired genetic targets may require alternative approaches alongside or instead of genome editing, potentially including transgenesis; in some cases, scientists must negotiate complex licensing agreements with third parties; and practitioners must have the support, skills, and experience to navigate international markets and regulatory agencies.

These complex yet essential factors are obscured by oversimplistic narratives that present genome editing as accessible and democratic, and those that present agriculture in Africa as monolithic and in need of technological advancement. Promoters of the technology would do well to wrestle with the institutional and structural inequities explored here. Indeed, by exploring these complex factors, we are by no means arguing against a particular technology. Instead, we aim to center the empirical realities and valuable insights offered by those who are leading experiments and policy building on the ground that shed light on the rhetoric and the realities underpinning the knowledge politics of genome editing. Such insights will play a crucial role in shaping the technology's trajectory moving forward.

## Data accessibility statement

Data supporting this study were obtained through interviews and are thus not publicly available due to human subjects protection. Questions regarding methodology should be directed to the corresponding author.

## Acknowledgments

The authors would like to thank their interlocutors for their time and insight; Alanna Taylor for her research assistance and coordination; Emily Fox, Melanie Bateman, Jimena Bonza, and Faizah Imam for their assistance in transcribing interviews; fellow attendees at the Gene Editing and the Future of Food in Africa workshop for offering such insightful and useful suggestions on a first draft; as well as Alastair Iles and 2 anonymous reviewers for their excellent feedback.

## Funding
This article was supported by the Jean Monnet Network "Genome Editing and Agricultural Policy, Practice and Public Perceptions," with the support of the Erasmus+ programme of the European Union (Agreement number: 611150-EPP-1-2019-1-CA-EPPJMO-NETWORK-2019-1887).

## Competing interests
The authors have no competing interests to declare.

## Author contributions
Contributed to conceptualization: JSR, MAS.

Contributed to investigation: JSR.

Contributed to writing—original draft: JSR, MAS.

Contributed to writing—review and editing: JSR, MAS, AK, AE, DG, GDS, KF.

Contributed to writing—addressing reviews: JSR, MAS, KF, DG, AE.

## References
**Abdallah, N**, **Hamwieh, A**, **Radwan, K**, **Fouad, N**, **Prakash, C.** 2022. Genome editing techniques in plants: A comprehensive review and future prospects toward zero hunger. *GM Crops & Food* **12**(2): 601–615.

**Abugu, M.** 2021. Gene editing key to improving Africa's staple crops. Alliance for Science. Available at https://allianceforscience.cornell.edu/blog/2021/08/gene-editing-key-to-improving-africas-staple-crops/. Accessed September 7, 2023.

**AgNews.** 2020. The "Healthy Crop" project—Research consortium lead by the Heinrich Heine University Düsseldorf is expanded by four additional institutions to defeat bacterial rice blight. *AgNews*.

**Ajates, R.** 2022. From land enclosures to lab enclosures: Digital sequence information, cultivated biodiversity and the movement for open source seed systems. *The Journal of Peasant Studies* **50**: 1056–1084. DOI: http://dx.doi.org/10.1080/03066150.2022.2121648.

**Akullo, D**, **Maat, H**, **Wals, AE.** 2018. An institutional diagnostics of agricultural innovation; public-private partnerships and smallholder production in Uganda. *NJAS: Wageningen Journal of Life Sciences* **84**(1): 6–12. DOI: http://dx.doi.org/10.1016/j.njas.2017.10.006.

**Andersson, JA**, **Sumberg, J.** 2017. Knowledge politics in development-oriented agronomy, in Sumberg, J ed., *Agronomy for development: The politics of knowledge in agricultural research*. London, UK: Routledge: 1–13.

**Bain, C**, **Lindberg, S**, **Selfa, T.** 2020. Emerging sociotechnical imaginaries for gene edited crops for foods in the United States: Implications for governance. *Agriculture and Human Values* **37**: 265–279. DOI: http://dx.doi.org/10.1007/s10460-019-09980-9.

**Bart, R**, **Taylor, N.** 2017. New opportunities and challenges to engineer disease resistance in Cassava, a staple food of African small-holder farmers. *PLoS Pathogens* **13**(5): E1006287.

**Bellis, E**, **Kelly, E**, **Lorts, C**, **Gao, H**, **DeLeo, V**, **Rouhan, G**, **Budden, A**, **Bhaskara, GB**, **Hu, Z**, **Muscarella, R**, **Timko, MP**, **Nebie, B**, **Runo, SM**, **Chilcoat, ND**, **Juenger, TE**, **Morris, GP**, **dePamphilis, CW**, **Lasky, J.** 2020. Genomics of sorghum local adaptation to a parasitic plant. *Proceedings of the National Academy of Sciences* **117**(8): 4243–4251.

**Benton, A.** 2015. *HIV exceptionalism: Development through disease in Sierra Leone*. Minneapolis, MN: University of Minnesota Press.

**Bergius, M**, **Buseth, JT.** 2019. Towards a green modernization development discourse: The new green revolution in Africa. *Journal of Political Ecology* **26**(1): 57–83.

**Beumer, K**, **de Roij, S.** 2023. Inclusive innovation in crop gene editing for smallholder farmers: Status and approaches. *Elementa: Science of the Anthropocene* **11**(1): 00089. DOI: http://dx.doi.org/10.1525/elementa.2022.00089.

**Borlaug, N.** 2000 Dec 6. We need biotech to feed the world. *Wall Street Journal*.

**Boyd, W.** 2013. Wonderful potencies? Deep structure and the problem of monopoly in agricultural biotechnology, in Schurman, RA, Kelso, DDT eds., *Engineering trouble: Biotechnology and its discontents*. Berkeley, CA: University of California Press: 24–62.

**Byerlee, D**, **Lynam, JK.** 2020. The development of the international center model for agricultural research: A prehistory of the CGIAR. *World Development* **135**: 105080.

**Canfield, M.** 2022. The ideology of innovation: Philanthropy and racial capitalism in global food governance. *The Journal of Peasant Studies*. DOI: http://dx.doi.org/10.1080/03066150.2022.2099739.

**Clapp, J**, **Ruder, S-L.** 2020. Precision technologies for agriculture: Digital farming, gene-edited crops, and the politics of sustainability. *Global Environmental Politics* **20**(3): 49–69.

**Curry, HA.** 2016. *Evolution made to order: Plant breeding and technological innovation in twentieth-century America*. Chicago, IL: University of Chicago Press.

**De Amstalden, M.** 2023 Apr 18. Synthetic biology: Give me a cell and I will feed the world. University of Birmingham. Available at https://www.birmingham.ac.uk/news/2023/synthetic-biology-give-me-a-cell-and-i-will-feed-the-world.

**Doudna, J.** 2023 Jan 27. Crispr wants to feed the world. *Wired*. Available at https://www.wired.com/story/crispr-gene-editing-climate/.

**Egelie, KJ**, **Graff, GD**, **Strand, SP**, **Johansen, B.** 2016. The emerging patent landscape of CRISPR-Cas gene editing technology. *Nature Biotechnology* **34**(10): 1025–1031. DOI: http://dx.doi.org/10.1038/nbt.3692.

**Ely, A**, **Friedrich, B**, **Glover, D**, **Fischer, K**, **Stone, GD**, **Kingiri, A**, **Schnurr, MA.** 2022. Governing agricultural biotechnologies in the United States, the

United Kingdom, and Germany: A trans-decadal study of regulatory cultures. *Science, Technology, & Human Values*. DOI: http://dx.doi.org/10.1177/01622439221122513.

**Flint, K.** 2020. "Africa Isn't a Testing Lab": Considering COVID vaccine trials in a history of biomedical experimentation and abuse. *Journal of West African History* **6**(2): 126–140.

**Gakpo, JO.** 2021. Ghana scientist turns to gene editing to improve sweet potato crop. *Cornell Alliance for Science*. Available at https://allianceforscience.cornell.edu/blog/2021/02/ghana-scientist-turns-to-gene-editing-to-improve-sweet-potato-crop/. Accessed September 7, 2023.

**Gill, C.** 2018. Cocoa CRISPR: Gene editing shows promise for improving the chocolate tree. *PennState News*. Available at https://news.psu.edu/story/521154/2018/05/09/research/cocoa-crispr-gene-editing-shows-promise-improving-chocolate-tree. Accessed September 7, 2023.

**Glover, D.** 2010. Exploring the resilience of Bt Cotton's 'pro-poor success story'. *Development and Change* **41**: 955–981. DOI: http://dx.doi.org/10.1111/j.1467-7660.2010.01667.x.

**Glover, D**, **Friedrich, B**, **Ely, A.** 2020. Genome editing in agriculture: Issues for policy and regulation. Policy Briefing. STEPS Centre. Available at https://steps-centre.org/publication/genome-editing-in-agriculture-issues-for-policy-and-regulation/. Accessed September 7, 2023.

**Glover, D**, **Venot, J**, **Maat, H.** 2017. On the movement of agricultural technologies: Packaging, unpacking and situated reconfiguration, in Sumberg, J ed., *Agronomy for development: The politics of knowledge in agricultural research*. London, UK: Routledge: 14–30.

**Hall, A.** 2005. Capacity development for agricultural biotechnology in developing countries: An innovation systems view of what it is and how to develop it. *Journal of International Development* **17**: 611–630.

**Hall, A**, **Dorai, K.** 2020. Agricultural research, technology and innovation in Africa: Issues and options. *The International Journal of Technology Management & Sustainable Development* **19**(1): 3–22.

**Hedgecoe, A**, **Martin, P.** 2003. The drugs don't work: Expectations and the shaping of pharmacogenetics. *Social Studies of Science* **33**(3): 327–364. DOI: http://dx.doi.org/10.1177/03063127030333002.

**Helliwell, R**, **Hartley, S**, **Pearce, W.** 2019. NGO perspectives on the social and ethical dimensions of plant genome-editing. *Agriculture and Human Values* **36**(4): 779–791. DOI: http://dx.doi.org/10.1007/s10460-019-09956-9.

**International Crops Research Institute for the Semi-Arid Tropics**. 2019. ICRISAT student researcher employs advanced technology for pearl millet trait development in US Collaboration. ICRISAT Happenings Newsletter. Available at https://www.icrisat.org/icrisat-student-researcher-employs-advanced-technology-for-pearl-millet-trait-development-in-us-collaboration/. Accessed September 7, 2023.

**International Pest Control**. 2019. First ever plantain resistant to banana streak virus. International Pest Control. Available at https://international-pest-control.com/wordpress/first-ever-plantain-resistant-to-banana-streak-virus/. Accessed September 7, 2023.

**International Service for the Acquisition of Agri-Biotech Applications**. 2021. Genome editing in Africa's agriculture 2021: An early take-off. Available at https://africenter.isaaa.org/wp-content/uploads/2021/04/GENOME-EDITING-IN-AFRICA-FINAL.pdf. Accessed September 7, 2023.

**Jasanoff, S** ed. 2004. *States of knowledge: The co-production of science and social order*. New York, NY: Routledge.

**Jefferson, OA**, **Lang, S**, **Williams, K**, **Koellhofer, D**, **Ballagh, A**, **Warren, B**, **Schellberg, B**, **Sharma, R**, **Jefferson, R.** 2021. Mapping CRISPR-Cas9 public and commercial innovation using the Lens institutional toolkit. *Transgenic Research* **30**: 585–599. DOI: http://dx.doi.org/10.1007/s11248-021-00237-y.

**Juma, C.** 2015. *The new harvest: Agricultural innovation in Africa*. Oxford, UK: Oxford University Press.

**Karavolias, N.** 2021a. Application of gene editing for climate change in agriculture. *Frontiers in Sustainable Food System* **5**: 685801. DOI: http://dx.doi.org/10.3389/fsufs.2021.685801.

**Karavolias, N.** 2021b. Gene editing: Powerful tool for managing climate change. Alliance for Science. Available at https://allianceforscience.cornell.edu/blog/2021/09/gene-editing-powerful-tool-for-managing-climate-change/. Accessed September 7, 2023.

**Kjeldaas, S**, **Dassler, T**, **Antonsen, T**, **Wikmark, O-G**, **Myhr, AI.** 2022. With great power comes great responsibility: Why 'safe enough' is not good enough in debates on new gene technologies. *Agriculture and Human Values* **40**: 533–545. DOI: http://dx.doi.org/10.1007/s10460-022-10367-6.

**Kock, MA.** 2021. Open intellectual property models for plant innovations in the context of new breeding technologies. *Agronomy* **11**(6): 1218. DOI: http://dx.doi.org/10.3390/agronomy11061218.

**Komen, J**, **Tripathi, L**, **Mkoko, B**, **Ofosu, DO**, **Oloka, H**, **Wangari, D.** 2020. Biosafety regulatory reviews and leeway to operate: Case studies from Sub-Sahara Africa. *Frontiers in Plant Science* **11**: 130. DOI: http://dx.doi.org/10.3389/fpls.2020.00130.

**Kuzma, J.** 2018. Regulating gene-edited crops. *Issues in Science and Technology* **35**(1): 80–85.

**Leach, M**, **Scoones, I**, **Stirling, A.** 2010. *Dynamic sustainabilities: Technology, environment, social justice*. London: Routledge.

**Lloyd, JR**, **Berger, D**, **Pillay, P.** 2021. South Africa should rethink regulations on genetically modified plants. Alliance for Science. Available at https://allianceforscience.cornell.edu/blog/2022/02/south-africa-should-rethink-regulations-on-genetically-modified-plants/. Accessed September 7, 2023.

**Logan, A.** 2020. *The scarcity slot: Excavating histories of food security in Ghana*. Oakland, CA: University of California Press.

**Maina, J.** 2018. Kenya looks to gene editing to grow its key food crops. Alliance for Science. Available at https://allianceforscience.cornell.edu/blog/2021/05/kenya-looks-to-gene-editing-to-grow-its-key-food-crops/. Accessed September 7, 2023.

**McIntire, J.** n.d. OneCGIAR is failing (and what to do about it). Preprint. DOI: http://dx.doi.org/10.13140/RG.2.2.20565.09441.

**Middelveld, S**, **Macnaghten, P.** 2021. Gene editing of livestock: Sociotechnical imaginaries of scientists and breeding companies in the Netherlands. *Elementa: Science of the Anthropocene* **9**(1): 00073. DOI: http://dx.doi.org/10.1525/elementa.2020.00073.

**Montenegro de Wit, M.** 2020. Democratizing CRISPR? Stories, practices, and politics of science and governance on the agricultural gene editing frontier. *Elementa: Science of the Anthropocene* **8**(1): 9.

**Moseley, W**, **Schnurr, M**, **Bezner Kerr, R.** 2015. Interrogating the technocratic (neoliberal) agenda for agricultural development and hunger alleviation in Africa. *African Geographical Review* **34**(1): 1–7.

**Mudziwapasi, R**, **Ndudzo, A**, **Nyamusamba, RP**, **Jomane, FN**, **Mutengwa, TT**, **Maphosa, M.** 2018. Unlocking the potential of CRISPR technology for improving livelihoods in Africa. *Biotechnology & Genetic Engineering Reviews* **34**(2): 198–215.

**Mueller, NG**, **Flachs, A.** 2022. Domestication, crop breeding, and genetic modification are fundamentally different processes: Implications for seed sovereignty and agrobiodiversity. *Agriculture and Human Values* **39**(1): 455–472. DOI: http://dx.doi.org/10.1007/s10460-021-10265-3.

**Murdock, A.** 2020. Using CRISPR genome editing to make cyanide-free Cassava. Berkley Research. Available at https://vcresearch.berkeley.edu/news/using-crispr-genome-editing-make-cyanide-free-cassava. Accessed September 7, 2023.

**Nang'ayo, F**, **Simiyu-Wafukho, S**, **Oikeh, S.** 2014. Regulatory challenges for GM crops in developing economies: The African experience. *Transgenic Research* **23**(6): 1049–1055.

**Ogaugwu, C**, **Agbo, S**, **Adekoya, M.** 2019. CRISPR in Sub-Saharan Africa: Applications and education. *Trends in Biotechnology* **37**(3): 234–237.

**Okwuonu, I.** 2021. Expert opinion on Cassava improvement in Africa through genome editing. Africa Science Media Centre. Available at https://afrismc.org/expert-opinion-on-cassava-improvement-in-africa-through-genome-editing/. Accessed September 7, 2023.

**Paarlberg, R**, **Smyth, SJ.** 2023. The cost of not adopting new agricultural food biotechnologies. *Trends in Biotechnology* **41**(3): 304–306. DOI: http://dx.doi.org/10.1016/j.tibtech.2022.09.006.

**Penn State**. 2020. Local genetic adaption helps sorghum crop hide from witchweed. *Proceedings of the National Academy of Sciences*.Available at https://www.eurekalert.org/pub_releases/2020-02/ps-lga021120.php. Accessed September 7, 2023.

**Pierre, J.** 2020. The racial vernaculars of development: A view from West Africa. *American Anthropologist* **122**(1): 86–98. DOI: http://dx.doi.org/10.1111/aman.13352.

**Pixley, KV**, **Falck-Zepeda, JB**, **Giller, KE**, **Glenna, LL**, **Gould, F**, **Mallory-Smith, CA**, **Stelly, DM**, **Stewart Jr, CN.** 2019. Genome editing, gene drives, and synthetic biology: Will they contribute to disease-resistant crops, and who will benefit? *Annual Review of Phytopathology* **57**: 165–188.

**Qaim, M.** 2020. Role of new plant breeding technologies for food security and sustainable agricultural development. *Applied Economic Perspectives and Policy* **42**(2): 129–150.

**Ricroch, A.** 2019. Global developments of genome editing in agriculture. *Transgenic Research* **28**(S2): 45–52. DOI: http://dx.doi.org/10.1007/s11248-019-00133-6.

**Rock, J.** 2022. *We are not starving: The struggle for food sovereignty in Ghana*. East Lansing, MI: Michigan State University Press.

**Rock, J**, **Schnurr, MA**, **Kingiri, A**, **Glover, D**, **Stone, GD**, **Ely, A**, **Fischer, K.** 2023. Beyond the genome: Lessons learned from genetically modified crops in Africa and the implications for genome editing. *Development and Change* **54**: 117–142. DOI: http://dx.doi.org/10.1111/dech.12750.

**Rodney, W.** 1982. *How Europe underdeveloped Africa*. Washington, DC: Howard University Press.

**Roe, E.** 1994. *Narrative policy analysis: Theory and practice*. Durham, NC: Duke University Press.

**Roseboom, J**, **Flaherty, K.** 2016. The evolution of agricultural research in Africa: Key trends and institutional developments, in Lynam, J, Beintema, NM, Roseboom, J, Badiane, O eds., *Agricultural research in Africa: Investing in future harvests*. Washington, DC: International Food Policy Research Institute (IFPRI): 31–58. DOI: http://dx.doi.org/10.2499/9780896292123_02.

**Schnurr, MA.** 2019. *Africa's gene revolution: Genetically modified crops and the future of African agriculture*. Montreal, QC: McGill-Queen's University Press.

**Schnurr, MA**, **Rock, J**, **Kingiri, A**, **Lieberman, S.** 2022. Are genetically modified and genome-edited crops viable strategies for climate-change adaptation among smallholder farmers? *Current Opinion in Environmental Sustainability* **58**: 101216. DOI: http://dx.doi.org/10.1016/j.cosust.2022.101216.

**Schurman, R.** 2016. Building an alliance for biotechnology in Africa. *Journal of Agrarian Change* **17**(3): 441–458.

**Shah, E**, **Ludwig, D**, **Macnaghten, P.** 2021. The complexity of the gene and the precision of CRISPR: What is the gene that is being edited? *Elementa: Science of the Anthropocene* **9**(1): 00072.

**Spielman, D**, **Hartwich, F**, **Grebmer, K.** 2010. Public–-private partnerships and developing-country agriculture: Evidence from the International Agricultural Research System. *Public Administration and Development* **30**(4): 261–276.

**Spielman, D**, **Zambrano, P.** 2013. Policy, investment, and partnerships for agricultural biotechnology research in Africa: Emerging evidence, in Spielman, D, Zambrano, P eds., *IFPRI book chapters*. Washington, DC: International Food Policy Research Institute (IFPRI).

**Thomas, D.** 2006. A general inductive approach for analyzing qualitative evaluation data. *The American Journal of Evaluation* **27**(2): 237–246.

**Travella, S**, **de Oliveira, D**, **de Buck, S**, **Lambein, F**, **Ngudi, DD**, **De Bauw, V**, **Gheysen, G**, **Van Montagu, M**, **Heijde, M.** 2019. Scientific innovation for the sustainable development of African agriculture. *Afrika Focus* **32**(2): 117–133.

**Tripathi, L**, **Dhugga, KS**, **Ntui, VO**, **Runo, S**, **Syombua, ED**, **Muiruri, S**, **Wen, Z**, **Tripathi, JN.** 2022. Genome editing for sustainable agriculture in Africa. *Frontiers in Genome Editing* **4**: 876697. DOI: http://dx.doi.org/10.3389/fgeed.2022.876697.

**Tutton, R.** 2011. Promising pessimism: Reading the futures to be avoided in biotech. *Social Studies of Science* **41**(3): 411–429. DOI: http://dx.doi.org/10.1177/0306312710397398.

**U.S. Agency for International Development**. 2022. Administrator Samantha Power at the World Food Prize Foundation's Annual Norman E. Borlaug International Dialogue. Speech, October 19, 2022. Available at https://www.usaid.gov/news-information/speeches/oct-19-2022-administrator-power-world-food-prize-foundations-annual-international-dialogue.

**van der Oost, J**, **Fresco, LO.** 2021. Waive CRISPR patents to meet food needs in low-income countries. *Nature* **597**: 178. DOI: http://dx.doi.org/10.1038/d41586-021-02397-7.

**Wartha, C**, **Lorenz, A.** 2021. Implementation of genomic selection in public-sector plant breeding programs: Current status and opportunities. *Crop Breeding and Applied Biotechnology* **21**(Spe): e394621S15.

**Winner, L.** 1980. Do artifacts have politics? *Daedalus* **109**(1): 121–136.

**Yapa, L.** 1993. What are improved seeds? An epistemology of the green revolution. *Economic Geography* **69**(3): 254–273.

**How to cite this article:** Rock, JS, Schnurr, MA, Kingiri, A, Ely, A, Glover, D, Stone, GD, Fischer, K. 2023. The knowledge politics of genome editing in Africa. *Elementa: Science of the Anthropocene* 11(1). DOI: https://doi.org/10.1525/elementa.2022.00143

**Domain Editor-in-Chief:** Alastair Iles, University of California Berkeley, Berkeley, CA, USA

**Knowledge Domain:** Sustainability Transitions

**Part of an Elementa Special Feature:** Genome Editing and the Future of Food in Africa

**Published:** September 15, 2023 **Accepted:** July 22, 2023 **Submitted:** November 23, 2022



ELEMENTA Science of the Anthropocene

*Elem Sci Anth* is a peer-reviewed open access journal published by University of California Press.

OPEN ACCESS