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RESEARCH ARTICLE

Tensions at the boundary: Rearticulating 'organic' plant breeding in the age of gene editing

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A host of technologies is rapidly entering agriculture. These new technologies—particularly gene editing—represent multifaceted shifts beyond "genetic modification" (GM), and are outpacing both public understanding and the capacity of regulatory regimes. This paper employs the case of the organic sectors in Canada and the United States, strongholds of GM resistance, to examine conversations about gene-editing technologies unfolding within the organic community, and elucidate their implications for the sector. We employ the concept of "boundary work" to illuminate how key actors and institutions delineate the concept of organic breeding in the face of emerging technologies. We draw upon semi-structured interviews with organic sector representatives, a review of documents published by organic organizations, and data from participant observation. We find that the organic community is reaffirming and deepening boundaries in response to arguments made by proponents of gene editing. Both internal and external pressures on the sector are facilitating a dampening effect on conversations about the boundaries between gene editing and organic agriculture, as the sector is compelled to present a united voice against the affront of new genetic technologies. The sector is also redrawing existing boundaries, as the advent of gene editing has forced conversations about the compatibility of both new and established breeding methods with organic. The resulting questions about what distinguishes acceptable levels of human intervention in plant genomes are highlighting some differences within the diverse organic community. We also argue that debates about gene editing and organic breeding may be "bounding out" important actors from deliberation processes, and note initial attempts to reckon with this exclusion.

Keywords: Gene editing; CRISPR-Cas9; Organic agriculture; Plant breeding; Genomics; Biotechnology

1. Introduction

A host of new genomic technologies is rapidly entering the food and agriculture industry. While the technification of agriculture is not a novel trend, this array of techniques—particularly gene editing, but also gene drives and synthetic biology—represents significant and multifaceted shifts beyond "genetically modified" (GM) and is quickly outpacing both public understanding and regulatory regimes (National Academies of Sciences, 2017; Shukla-Jones et al., 2018). This upshift in technological capability is creating renewed discord between proponents of these techniques, regulatory agencies, and actors resisting what they perceive as a problematic technological development. The papers brought forward in this special issue seek to illuminate the tensions that this new wave of agricultural gene editing technologies is generating.

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The organic seal is one of only a few existing guarantees for eaters that their food does not contain genetically modified organisms (GMOs) (Organic Trade Association, 2020). Indeed, the organic community and sector is viewed by many as an "anti-GM" stalwart as a result of their united and international opposition to the first wave of GMOs in the food system (International Federation of Organic Agriculture Movements, 2016). Given that the organic community's stance symbolizes for many the mark of "good" food, its attitudes towards these technologies have had far-reaching implications for farmers and eaters alike. Despite this group's (op)position and history of engaging with controversy around genetic modification technologies, and despite scholarly attention to the conceptual compatibility of organic and gene editing, i.e., whether some versions of gene editing may be in alignment with organic values (e.g., Andersen et al., 2015a; Palmgren et al., 2015; Wickson et al., 2016; Ryffel, 2017), the sector's responses to gene editing have received little to no attention in the form of empirical study. Particularly in light of signals from the United States (U.S.) that its agencies will not strictly regulate gene-edited crops (U.S. Department of Agriculture, 2018),[1] and the increased arguments from proponent scientists and governments heralding precision and accessibility (Goold et al., 2018), these technologies are likely to have implications for the integrity of organic plant breeding and organic agriculture more broadly.

This paper seeks to address the gap in scholarly attention to the organic community's responses to gene editing, and asks specifically how members of the organic community in the United States and Canada are viewing new gene editing technologies relative to GM (genetic modification), what logics and rationales underpin their responses, whose views are included in these conversations, and what tensions are being raised in the process.

This research focuses on the organic community and gene-editing technologies in Canada and the United States. We limit our analysis to Canada and the United States because of the size of these markets, their tightly coupled trade systems, their relatively high proportion of agricultural land in organic acreage, and their exposure to similar pressures and contexts (Willer et al., 2020). In this paper, we refer to both the organic "sector" and the organic "community", as "organic" is both a distinct agricultural industry and supply chain, and a social movement grounded in relationships and values. We refer primarily to institutions engaged with organic farming as a key (if not exclusive) focus of their work, rather than the broader base of organic eaters or value chain actors involved in processing and marketing organic food. We also focus primarily on plants or crops as opposed to livestock, as gene-editing applications to plants are more advanced and these alone came up in our data collection. For our purposes, we use "GM" to describe recombinant DNA techniques used to produce transgenic organisms commonly known as GMOs, debates over which came to a head in the mid 1990s. We use "gene editing" to refer to the suite of technologies that has expanded particularly in the most recent decade (e.g., CRISPR-Cas9, clustered randomly interspaced palindromic repeats and CRISPR-associated protein 9).[2] These techniques make it possible to modify organisms in faster and more targeted ways than with recombinant DNA techniques, and are being discussed as a 'new and improved' version of GM (Agapito-Tenfen et al., 2018).

Our objective is not to comment on the validity or strength of arguments presented for or against gene editing, but rather to examine the conversations that are unfolding within the organic community, and elucidate the implications of these conversations for the sector's ability to operationalize its core values-based principles such as ecology, health, fairness, and care (International Federation of Organic Agriculture Movements, 2020). In addition to gene editing, we also discuss technologies that we call "other breeding techniques". These include a range of both newer and older methods not usually considered under the umbrella of biotechnology, but central to the broader re-evaluation of the sector's approach to breeding technology that decisions around gene editing have triggered. Some of these techniques are based in the study of genomics (e.g., marker-assisted selection, which relies on genomics but does not involve any genetic manipulation or intervention), whereas others pre-date the field of genomics (e.g., induced mutagenesis, which involves the use of irradiation, chemicals, and other means to generate mutations for breeding purposes). These definitional lines are not simple or clear, and exploring this conceptual and technical ambiguity is one of the goals of this paper.

We begin by summarizing the historical relationship and conceptual compatibility between organic principles and biotechnology, present our theoretical and conceptual framing on boundary work and boundary organizations (Guston, 2001) and apply this lens to the organic sector (following Ingram, 2007; DuPuis and Gillon, 2009). We trace how the sector is re-articulating boundaries between what are legitimate organic breeding practices or not, and in more implicit ways, between who can participate in deliberation on this topic or not. We find that the organic community opposes gene editing on similar grounds to its historical opposition to GM, thus reasserting the boundary between "organic" and "biotechnological". The sector is also deepening the articulation of this boundary by directly contesting the distinctions that proponents use to differentiate gene editing from GM, such as claims that it might be more democratic or inclusive, and heightened concerns around issues of transparency. We also find that both internal and external pressures are dampening conversations on boundary setting between gene editing and acceptable organic breeding methods. We assert that the reason for the sector's outward unanimous rejection of gene editing is linked, at least in part, to the high stakes of losing consumer trust amidst technically complex and polarizing biotechnology debates, and the need to provide farmers with clear guidelines to follow.

We also find that the discourse around gene editing is facilitating the redefinition of the boundaries around organic breeding more broadly. As a result of the need to clarify exactly on what basis certain breeding methods are compatible with organic or not, this boundary-making raises challenging ontological questions, such as around questions of naturalness and its variety of possible interpretations. Finally, we argue that discussions on gene editing and breeding techniques more broadly may have "bounded out" important actors and highlight some tensions inherent in this boundary work between inclusion for the sake of democratic dialogue, and exclusion in the name of expedient decision-making. As such, biotechnology may act as a red herring, leading parts of the organic community to prioritize navigating tensions around acceptable breeding methods over other priorities such as advancing organic plant breeding and organic seed sector development.

2. The organic sector and responses to biotechnology

In this section we briefly introduce gene editing technologies, situate these in the context of GM, and summarize initial responses to their purported benefits. We next review existing scholarly work on the compatibility of organic agriculture with modern biotechnology, and explore how gene editing may affect the conclusions from this body of research. We then introduce the concept of "boundary work" and associated theory, and apply these to the organic sector in the United States and Canada.

2.1. Gene editing: A 'better' GM?

Objections to GM technology have been fierce, and have been articulated differently by a variety of actors. In the Global South, these objections have been voiced largely by groups organizing around seed sovereignty and farmers rights, as GM carries intellectual property restrictions that inhibit breeding and seed-sharing practices (Tripp, 2001; Scoones, 2002; Soleri et al., 2008; Stone, 2010; Kinchy, 2012; Schnurr and Mujabi-Mujuzi, 2014).[3] In the United States and Canada, consumer health concerns have been a more prominent area of objection (Stone, 2002), although some key groups have also followed the Global South in framing opposition to GM in terms of corporate control and rights of farmers and seed savers, including the National Farmers' Union in Canada and the US Food Sovereignty Alliance (National Farmers Union, 2000; US Food Sovereignty Alliance, 2014). Indigenous communities in the United States and Canada have also organized in opposition to GMOs on the grounds that, in various ways, genetic modification and related patenting of seeds conflicts with Indigenous worldviews regarding seeds as sacred cultural heritage and relatives (LaDuke, 2004; Gugganig, 2017; Hoover, 2017). Given the intense controversy and disagreement over GMOs, no conversation on gene editing and organics can fully escape its polarizing legacy.

If GM set a new precedent in the 20th century for human intervention in the genome, what will occur in this next period as gene editing further expands biotechnological capabilities? Gene editing[4] is a class of techniques that vary in the specific forms of genomic intervention involved. All involve making modifications to the genome, but unlike GM, versions of gene editing generally (1) involve targeted modifications to the genome, and (2) do not necessarily involve transgenesis, or the insertion of genetic material from another organism or species (Lusser and Davies, 2013; Hartung and Schiemann, 2014).

Due to their ability to be more easily and cost-effectively tailored to different applications, CRISPR/Cas9 and other iterations of CRISPR techniques occupy much of the contemporary science and policy discussion on gene editing. CRISPR techniques involve creating proteins to recognize a specific DNA sequence in a target genome, bind to it, and cut it. Then, the cell itself repairs the break in a way that alters the original genomic sequence and, often, leaves no transgenic material in the resulting plant (Zaidi and Mansoor, 2017; Jaganathan et al., 2018).

Proponents of gene editing profess a range of advantages of gene editing over GM, notably that gene editing will be more acceptable to publics than GM because it involves a more precise and specific modification to the genome of the target organism without introducing any foreign DNA. While the vast majority of GM crops are either herbicide tolerant or insect resistant via *Bacillus thuringiensis*, and are largely applied to grains and oilseeds like corn, soy, and canola (Jacobsen et al., 2013), proponents also argue that gene editing may be more easily used to develop new types of traits and more readily applied to a wider variety of plant species as a result of its relative affordability and customizability (Goold et al., 2018).

Proponents also compare these techniques to older forms of irradiation- or chemical-based mutagenesis, techniques that have been used to develop traits in many crop varieties used in both conventional and organic agriculture. With such forms of mutagenesis, breeders apply either chemicals or radiation to seeds with the intention of generating mutations that create useful traits for breeding into existing lines. Proponents argue that traditional breeding already makes use of spontaneous mutations and mutagenesis and that gene editing is a more targeted and specific form of mutagenesis (Andersen et al, 2015). Crucially, they argue that the changes that arise are no different from those that occur naturally, as resulting products cannot be distinguished from those developed via other breeding techniques, and are thus more "natural"—unlike GMOs, whose GM status can be tested. As such, they argue that gene editing is a less risky, more acceptable form of biotechnology—indeed, that it represents a "GM 2.0"(Cotter and Steinbrecher, 2016). Proponents point out that, unlike with GM where organisms are produced that never could have emerged via traditional breeding, gene-edited crops are indistinguishable from those bred traditionally, and should thus be viewed as comparable (National Academies of Sciences, 2017).

In their examination of how proponents of gene editing in agriculture discuss these new applications, Bain et al. (2019) find that three key "sociotechnical imaginaries" characterize these discourses: (1) gene-edited organisms are not GM, and instead are more like those bred conventionally; (2) they have the potential to bring about a new Green Revolution; and (3) they might help democratize agricultural biotechnology. These imaginaries serve to distinguish gene editing techniques as less threatening and more palatable than GM in efforts to avoid equivalent public controversy.

Several initial studies have explored the grounds on which opponents of gene editing technologies—largely represented by civil society actors—contest claims made by proponents. In another paper in this special issue, Montenegro de Wit (2020) notes that unlike many of the other claims that proponents make about gene editing, the promise of being more 'democratic' aligns with the objectives of food sovereignty and agroecology movements who typically oppose GM on these grounds. However, Montenegro de Wit finds that this claim of democratization conflates affordability with accessibility, and does not consider that farmers and other actors may not have the sufficient knowledge, materials, or infrastructure to successfully harness this technology for their own purposes. In response to the portrayal of NGOs who oppose gene editing as emotional and dogmatic, Helliwell et al. (2019) elucidate key logics of opposition employed by EU-based NGOs with interests in agriculture, finding that participants contested: (1) proponents' framing of the food security problem as one of insufficient food; (2) the ability of gene editing to solve problems created by the industrial agricultural model; and (3) proponents' underlying motivations for pursuing gene editing. These studies provide valuable evidence to suggest that the organic sector may similarly contest proponent claims that gene editing is substantially different from GM, as well as the possible nature of these logics of opposition.

2.2. Gene editing and organics?

Might modern biotechnology be compatible with organic agriculture? The question has received renewed interest, building on earlier studies considering the utility of GM for the organic sector, such as Ronald and Adamchak (2008), Ceccarelli (2014), and Husaini and Sohail (2018). These scholars suggest that GM seed, if cultivated using organic management practices, could reap the benefits of increased yields—without increased use of inputs—by breeding for traits such as disease resistance, drought tolerance, and enhanced productivity. There is also a substantial literature that examines the alignment between plant breeding technologies and internationally-articulated principles of organic agriculture as put forward by the International Federation of Organic Agriculture Movements (IFOAM) (see in particular Lammerts Van Bueren et al., 2003; Lammerts Van Bueren, 2010; Lammerts van Bueren et al., 2011; Andersen et al., 2015). This discussion lays out the foundations for the organic community's opposition to GM technologies in reference to principles of ecology, health, fairness, and care. The implications of these principles for guiding organic plant breeding—i.e., what forms of plant breeding the international organic community is *for*, rather than against—are summarized below in **Table 1**.

More recently, scholars have considered the potential compatibility of gene editing with the principles of organic plant breeding. Nuijten et al. (2017) argue that gene editing violates the integrity of living entities, because it makes a change within a plant cell, which they consider to be the most fundamental level of self-organizing life, as plants regenerate from single cells. Others argue that IFOAM's principles are inherently incompatible with gene editing due to the agro-industrial context in which gene editing has arisen, combined with a lack of attention to social and political implications of the technology; they contest the problem framing that gene editing purports to address (Wickson et al., 2016; Helliwell et al., 2019). For gene editing to be embraced, they argue, proponents need to address issues of ownership, regulatory assessment, and containment, as well as fully explore existing alternatives. On the other hand, Andersen et al. (2015) see areas of possible compatibility in using gene editing to facilitate more targeted breeding for traits that are desirable in organic systems, such as introducing traits from crop wild relatives for disease resistance and drought tolerance, thus supporting organic principles of health and ecology.

2.3. Conceptualizing "boundary work" in the organic sector

The pioneers of organic agriculture were largely concerned with soil health as the basis for sustainable agricultural production, with an emphasis on "the law of return"—that is, recycling organic matter and nutrients through mulching, composting, and application of manure (Howard, 1940; Conford, 2001). With the current institutionalized framework and legal standards accompanied by an explosion of organic food availability at retail outlets across North America, the growth and expansion of the organic sector can be considered in many respects as a great success (Willer and Lernoud, 2018). Yet critics of organic sector's evolution call into question whether the contemporary practice of organic agriculture is in line with the values-based principles, or the vision of the organic pioneers (Darnhofer et al., 2010; Seufert et al., 2017). Scholars have explored how codification and institutionalization of organic practices into a legal framework have diluted the holistic foundations, and how the rise in third-party certification has exacerbated tensions between profit-seeking newcomers to the organic market, and between those who identify as being part of the organic movement (Guthman, 2004a; Guthman, 2004b; Lockie and Halpin, 2005; Obach, 2015). Rather than wading into this "conventionalization" debate—the process by which the organic sector has come to resemble the so-called conventional agricultural sector (Buck et al., 1997)—we focus on how new forms of biotechnology are requiring the organic community to take a more explicit position on what is and is not organic breeding, and why. While we refer to the "organic community" in singular throughout this paper, we would like to emphasize here the diverse and multi-faceted composition of communities engaged with "organics": it is far from monolithic, representing at once a values-based community, social movement, scientific research field, set of agronomic practices, network of economic enterprises, and a policy space.

To understand how the community is responding to gene editing in the context of this multidimensional sector and movement, we employ the concept of "boundary

Table 1: Implications of organic principles for plant breeding following Lammerts van Bueren (2010). DOI: https://doi.org/10.1525/elementa.429.t1

Principle	Consequence of IFOAM principle for plant breeding
Health	Maintains wholeness and integrity of living systems and organisms, and promotes robustness and resilience
Ecology	Supports optimal functioning of ecosystems through regional adaptability, and decentralized and participatory breeding for ecologically beneficial traits
Fairness	Serves equity respect, justice and stewardship of our shared world, including free access to genetic resources, prohibiting patents on life, and benefit sharing.
Care	Enhancing efficiency and productivity in a precautionary an responsible manner.

work." Boundary work, as originally theorized, is the work that various actors do to create and maintain distinctions between what science is and what it is not (Gieryn, 1983). More recently, scholars have applied the concept of boundary work to the organic sector to understand the processes by which the sector distinguishes organic food from conventional food, and through which certain interpretations of organic are legitimized and others de-legitimized (Ingram, 2007; DuPuis and Gillon, 2009). Similarly, in the context of this study, "boundary work" can be understood to involve the processes by which actors understand the acceptability of different breeding technologies, and how they create such distinctions as GM vs. gene-edited and organic vs. non-organic.

A related concept is that of boundary organizations, which are a diversity of institutional spaces that exist at the nexus of science and politics and thereby have the ability to influence both (Guston, 2001; Forsyth, 2003). Boundary organizations facilitate collaboration between different actors, including scientists and non-scientists, often acting as intermediaries on topics that are controversial by setting definitions or terms of debate (Forsyth, 2003). Given the importance of farming and food production as practices at the core of the organic sector, we amend Forsyth's (2003) definition of boundary organizations as sites of science and policy to also include "practice." The sector comprises a number of organizations simultaneously involved not only in the science and policy but also practice of organic agriculture, "tethered" to each of these activities by the "coproduction of mutual interests" (Guston, 2001, p. 405). Viewing these organizations this way helps us capture the institutional complexity of those we engaged with for this research, and their connections to multiple corners of the organic agricultural community, as well as outside of it. Thus, we operationalize this concept in reference to the various organic sector organizations that engage in any combination of (1) standard setting, (2) convening of different actors in the sector, (3) research (e.g., on crop breeding), and (4) advocacy towards the coproduction of science, policy *and practice* of organic agriculture. While Guston (2001) focuses on singular boundary organizations and Ingram (2007) has similarly focused on a single boundary organization in the organic sector, we approach the organic sector as comprising numerous boundary organizations that function together via these four sets of activities to delineate the concept of organic and what types of breeding methods are acceptable within it. We give particular attention to two organizational bodies (and participating actors) in the United States and Canada, respectively, as they lead the development of the organic standards, and play an especially important role in decisions (and boundary-making) regarding permitted practices and substances, including on gene editing.

One of the critiques of boundary work, boundary organizations and the theory that underpins these concepts (e.g., Callon, 1984; Latour, 1987), is its lack of attention to questions of power imbalances that may exist between actors (e.g., Hawkins et al., 2017). Ingram (2007) finds that while boundary organizations have the potential to create productive tensions, in the US organic sector, these tensions are often *unproductive* due to concentration of power in the hands of a few key players, which stymies new ideas and perspectives. Standards such as jurisdictional organic standards emerge as a result of boundary work (Star, 2010). Standards are means of compromising across diverse values in power-laden ways, as they embed these values such that the standard setter has power to drive the actions of others (Busch 2011). As the organic community rearticulates its standards in light of gene editing technologies, we aim to explore where boundaries are reified versus redrawn, and the implications for the broader social, environmental, and political goals of the organic sector.

Together, the related concepts of boundary work and boundary organizations can help us ask: how do boundary organizations set relevant demarcations of what is organic, GM, or gene-edited? In light of more recent critiques of boundary work as a concept, how are rapidly evolving gene-editing technologies deepening existing boundaries in the organic sector, versus upending or redrawing them, and what are the implications of this reification or redrawing? And lastly, whose voices are included in relevant discussions, and whose are not?

3. Methods

We employ a multi-method approach, combining semi-structured interviews, participant observation, and narrative synthesis. Our sampling frame is boundary organizations (and affiliated individuals) from the United States and Canada involved in (1) standard setting, (2) convening, (3) research or (4) advocacy towards science, policy and practice of organic agriculture, including key international organizations with particular influence on and presence in North America (e.g., IFOAM).

We identified interviewees through a combination of purposive and snowball sampling based on their involvement with key boundary organizations and conversations on biotechnology in the organic sector. We conducted 19 semi-structured interviews with members of the organic community, including: four representatives of organic standards committees; six members of organic and food sovereignty civil society organizations (e.g., Organic Seed Alliance, Canadian Biotechnology Action Network, ETC Group); six plant breeders and researchers working at publicly funded institutions; and three plant breeders working at private companies (including those that only breed for organic agriculture as well as those that breed for both organic and conventional agriculture). Two interviewees are full-time farmers and others have farming experience. Interviews focused on similar themes, though the particulars were tailored depending on the jurisdictional context (the United States vs. Canada) and experience of the interviewee. With these questions, we sought to explore: (1) familiarity with gene editing and emerging genomics-related plant breeding techniques and ways of categorizing types of gene-editing and genomic-based breeding methods, (2) comparisons of these, particularly gene editing with GM, (3) overall views on gene editing and emerging breeding methods, (4) reasons for opposing or supporting these methods, (5) impressions about broader discussions and debates on these topics amongst the organic community, and (6) involvement in political engagement or advocacy around these methods. Throughout interviews, we asked about both participants' individual views on technologies, as well as the views held by or debates within the organizations or groups they were involved with. We were careful to clarify where they were representing their own views, and where they felt comfortable sharing views on behalf of these organizations or groups.

One author conducted participant observation at the Organic Seed Growers Conference (OSGC), in Corvallis, Oregon from February 12–15, 2020. OSGC is run by Organic Seed Alliance, and is a key location where organic farmers, businesses, seed growers, and plant breeders come together to discuss current developments in organic seed and plant breeding. Though it draws attendees primarily from the United States, Canadian farmers and researchers also attend. Participant observation at the 2020 conference involved attending sessions relevant to genomics including a two-hour session on "Excluded methods: An industry perspective" and sessions in the "Seed Ethics" track.

Two authors (Lyon and Klassen) also conducted participant observation at the Certified Organic Associations of British Columbia (COABC) conference in Richmond, British Columbia (BC) from February 28-March 1, 2020, including sessions on "Where is genetic engineering headed?", an update on the review of the organic standards, and broad visioning for the organic sector in BC. COABC administers BC's organic accreditation program and engages in public outreach and policy advocacy related to the organic sector in the province. Their annual conference is primarily attended by organic farmers and certifiers from BC, but also draws researchers and other stakeholders from within and outside the province. Two of us (Lyon and Klassen) also draw on contextual knowledge from our ongoing engagement in long-term participatory projects with the organic sector in the United States and Canada for this paper.

Interviews were audio-recorded and transcribed. Along with participant observation notes, these were coded using NVivo, a qualitative coding software. Two authors coded all transcripts and notes inductively and compared codes to explore similarities and differences. To cross-check understanding of codes and emergent themes, we discussed findings at scheduled intervals during the interviewing, transcribing, and coding process.

We also conducted a narrative synthesis in order to triangulate findings from interviews and participant observation. The goal of the narrative synthesis was to understand what decisions or statements regarding gene editing have been made by relevant organizations, and how these more public-facing documents compare to conversations with key informants. We first conducted internet searches using Google of the terms "gene edit*" and "organic" to uncover any available written content from organic and allied organizations on the subject. The identified documents included meeting discussion documents, legal standards, leaflets, petitions, policy memos, position statements, position papers, public comments, and web pages. We used content analysis to assess the types of responses and logics used in support of arguments (see Supplementary Material). We used the following inclusion criteria to narrow our scope for this narrative synthesis: documents that focused on emerging issues of gene-editing, and written by boundary organizations relevant to the jurisdictional context of the United States or Canada (as defined above). We also conducted follow-up searches of specific boundary organizations identified throughout this research, along with the term "gene edit*".

4. Findings and discussion

In this section, we (1) outline recent developments around gene editing that have unfolded in key boundary organizations; (2) examine responses to gene editing and explore how the sector is demarcating the bounds of organic plant breeding in relation to both GM and newer technologies; (3) introduce emerging discussions around the acceptability of other breeding methods for the organic sector, and the growing need to articulate clearer boundaries around organic breeding; and (4) reflect on how these new challenges around governance of breeding methods have additional implications for the "bounding out" or exclusion of important voices in the sector.

4.1. Boundary making via organic standards

The organic programs in the United States and Canada both involve technical advisory bodies that gather research and information, deliberate, and provide guidance or make decisions on how the organic standards should best reflect the interests of the sector. These technical advisory bodies act as boundary organizations that interface with scientists, industry associations, government regulatory agencies, and civil society organizations. They consist of representatives from farming, processing, and retail, as well as environmental protection and public interest groups.

In the United States, the organic sector is regulated by the US Department of Agriculture (USDA) under its National Organic Program (NOP), with the National Organic Standards Board (NOSB) acting as a semi-independent advisory body to the NOP. The NOSB has 15 members who are all appointed by the US Secretary of Agriculture and serve 5-year terms, as well as six subcommittees that develop proposals and discussion documents for the full NOSB's consideration (United States Department of Agriculture, n.d.). The NOSB functions similarly to an advocacy group by making proposals and arguments to the USDA, which is the body that retains ultimate decision-making authority. While changes to the organic standards must undergo a public comment period where input is received from the organic community, it is the USDA, not the NOSB, that makes final decisions about the standards and associated certification and regulatory frameworks (United States Department of Agriculture, 2015; United States Department of Agriculture, n.d.).

In contrast, the Canadian General Standards Board (CGSB) Committee on Organic Agriculture (also called the "Technical Committee") is the ultimate governing body of the Canadian organic standards. This committee includes 40 elected representatives of various organic-related organizations. Similar to the NOSB in the United States, the Technical Committee is supported by an even wider group of subcommittees that weigh in on specific topics. While this committee operates under the auspices of the CGSB (a government body that offers standards development and conformity assessment services), the standards are established by consensus and approved by the Technical Committee (Government of Canada, 2019).

Several informants who have been involved with standard-setting on both sides of the US-Canada border contrasted the relatively more democratic standard-setting process in Canada to the more absolute ownership of the US standards by the USDA. An interviewee also noted that there may be more political interference in the standards from Congress legislators and government staff in the United States than by their counterparts in Canada. Another difference between the two jurisdictional contexts is the existence of OSA and the Organic Seed Growers and Trade Association (OSGATA), which act as strong conveners and organizers for the organic seed sector in the US, as compared to the more nascent and regional organization of the organic seed sector in Canada.

We assert that these two organizational bodies—the NOSB in the US and the Technical Committee in Canada—are key boundary organizations for the organic sector, as they are a space for discussion and decisions to be made on key issues for the organic sector at the intersection of scientific, political, and practical concerns. In terms of recent developments on biotechnology, both the Canadian and US organic standards (and accompanying regulatory programs) have explicitly excluded gene editing from accepted breeding methods in organic agriculture in their respective jurisdictions.

As a part of the 2020 review of the Canadian organic standards (which happens every five years, and is currently in progress), the Technical Committee identified the need to rewrite the definition of genetic engineering to more clearly state that "genetic modifications and certain other new technologies, such as gene editing, are not allowed" (Organic Federation of Canada, 2020). The use of gene editing will thus be prohibited in the next round of standards, which is expected to be released in November 2020. According to the Chair of the Technical Committee, they had attempted to write their original definition of "genetic engineering" (rather than using the language of GMOs) preventatively, such that it will encompass other technologies including but not limited to gene editing in the future. Given that this revision is currently underway, the specific language included below (**Table 2**) is under review as a draft and has not yet been approved (Canadian General Standards Board, 2019).

In the US, the National Organic Standards Board (NOSB) recommended in 2016 that the National Organic Program (NOP) begin developing a formal guidance document that would clarify which breeding methods were excluded and unacceptable as part of US organic farming (National Organic Standards Board, 2019). The Excluded Methods Subcommittee of the NOSB has continued to meet biannually to refine and complete this list. The definition of "excluded methods" under the NOP's organic regulations is:

Table 2: Draft revised definition of genetic engineering for approval by the Canadian Committee on Organic Agriculture. DOI: https://doi.org/10.1525/elementa.429.t2

Genetic engineering (also commonly known as resulting in Genetically Modified Organisms (GMO)) is the artificial manipulation of living cells for the purpose of altering its genome, constitutes genetic engineering and refers to a set of techniques from modern biotechnology by which the genetic material of an organism is changed in a way that does not occur other than through traditional breeding by multiplication and/or natural recombination. The genome is respected as an indivisible entity, and artificial technical/physical insertion, deletions, or rearrangements in the genome constitute genetic engineering. Techniques developed in future may be considered genetic engineering. Examples of the techniques used in genetic engineering include, but are not limited to: · genome/gene editing techniques, such as but not limited to CRISPr, that replace one DNA sequence with another, transposes, deletes or adds a gene sequence or a part of gene sequence; · recombinant DNA (rDNA) techniques that use vector systems; · cisgenesis; · intragenesis; · agro-infiltration; · techniques involving the direct introduction into the organism of hereditary materials prepared by whatever means, inside or outside the organism; · cell fusion (including protoplast fusion) or hybridization techniques that overcome natural physiological, reproductive or recombination barriers, where the donor cells/protoplasts do not fall within the same taxonomic family or are created outside, or manipulated within the organism through techniques such as, but not limited to synthetic biology. Unless the donor/recipient organism is derived from any of the above techniques, examples of techniques not covered by this definition include: · in vitro fertilization; · conjugation, transduction, transformation, or any other natural process; · polyploidy induction; · cell fusion (including protoplast fusion) or hybridization techniques where the donor cells/protoplasts are in the same taxonomic family and not created outside, or manipulated within, the organism through techniques such as, but not limited to, synthetic biology.

> *A variety of methods used to genetically modify organisms or influence their growth and development by means that are not possible under natural conditions or processes and are not considered compatible with organic production.*

Immediately upon the establishment of this new Excluded Methods list, gene editing techniques were placed on it. The NOSB's criteria for establishing and developing this list are provided in **Table 3** below. The list of excluded methods is provided in **Table 4**. The slightly more detailed guidelines evident from the US NOSB documents are perhaps a function of the distinctly different processes and governance models for standard setting in the two jurisdictions, whereby the NOSB must make recommendations to the USDA, requiring more detailed documentation (in contrast to the CGSB Technical Committee, which makes decisions more autonomously).

4.2. New technologies, bolstered boundaries?

In responding to gene editing, the organic sector is both affirming existing boundaries between the biotechnological and the organic, and deepening them by articulating logics of opposition in direct response to claims made by proponents. Across both interviews and the narrative synthesis, we find that the reasons that organic community members oppose gene editing are similar to many of the historical arguments made against GM, and interviewees were clear that they saw gene editing as another, albeit newer, form of genetic engineering that raises the same fundamental concerns. **Table 5** summarizes these overlapping concerns, along with data from the interviews or narrative synthesis to illustrate each.

Overarching in many comments was the perception that gene editing is a product of a flawed political-economic system, and as such, perpetuates rather than challenges this system. While most of the logics of opposition raised by our informants were not substantially different from previously articulated concerns around GM, responses did explicitly counter some of the arguments for gene editing made by proponents, reflecting an evolution in thinking and sharpening of views held by participants in response to purported benefits. For example, some interviewees questioned the promise of targeted edits, citing concerns that new studies have challenged this supposed precision. Another argued that even small precise edits may be creating off-target effects and unwanted changes. Moreover, several interviewees introduced the idea of "precision" as a ruse: they emphasized the importance of paying attention not just to how targeted or precise a technology is, but rather, whether or not it fits with organic values. As one individual expressed in the gene editing session at the COABC conference, it was not a discussion regarding the precision of gene editing that they wanted, but rather a conversation about "values and the vision for food and farming."

Table 3: NOSB criteria for breeding methods to be excluded under organic agriculture, from National Organic Standards Board (2019). DOI: https://doi.org/10.1525/elementa.429.t3

1. The genome is respected as an indivisible entity, and technical/physical insertion, deletions, or rearrangements in the genome is refrained from (e.g., through transmission of isolated DNA, RNA, or proteins). In vitro nucleic acid techniques are considered to be an invasion into the plant genome.
2. The ability of a variety to reproduce in a species-specific manner has to be maintained, and genetic use restriction technologies are refrained from (e.g., Terminator technology).
3. Novel proteins and other molecules produced from modern biotechnology must be prevented from being introduced into the agro-ecosystem and into the organic food supply.
4. The exchange of genetic resources is encouraged. In order to ensure farmers have a legal avenue to save seed and plant breeders have access to germplasm for research and developing new varieties, the application of restrictive intellectual property protection (e.g., utility patents and licensing agreements that restrict such uses to living organisms, their metabolites, gene sequences, or breeding processes) are refrained from.

Table 4: NOSB excluded methods (adapted from NOSB 2019). DOI: https://doi.org/10.1525/elementa.429.t4

- Targeted genetic modification, synthetic gene technologies, genome engineering, gene editing, gene targeting, including meganucleases, zinc finger nucleases, oligonucleotide-directed mutagenesis, transcription activator-like effector nucleases, CRISPR/Cas9, and others
- Gene silencing, including RNA-directed DNA methylation, RNA interference
- Accelerated plant breeding techniques, including reverse breeding, genome elimination, FasTrack Fast flowering
- Synthetic biology
- Cloned animals and offspring, including somatic nuclear transfer
- Plastid transformation
- Cisgenesis
- Intragenesis
- Agro-infiltration
- Transposons (developed via use of in vitro nucleic acid techniques)
- Induced mutagenesis (developed via use of in vitro nucleic acid techniques)

Table 5: Reasons for opposing gene editing based on interviews and narrative synthesis. DOI: https://doi.org/10.1525/elementa.429.t5

Logics of opposition to gene editing	Example from interviews or synthesis review	Examples of related arguments made about GM
Involving environmental risks and uncertainty	"Even the intended alteration can inadvertently alter other important genes, causing changes in chemistry or protein production that can be important for food and environmental safety." (CBAN—SM)	Trewavas and Leaver (2001); Stone (2002)
Involving health risks and uncertainty	"Assessment of public safety should involve the health effects of consumption (of the organism itself or of its products)." (IFOAM—SM)	Stone (2002); Frewer et al. (2004); Frewer et al. (2013)
Not holistic or ecologically integrated	"[Organic agriculture attempts] to mimic natural systems within our agricultural systems. Well… there's not really any way in which these technologies are even remotely attempting to mimic a natural system."	Altieri (2009)
Violating the integrity of the "cell wall" or genome	"Well, to make a blunt analogy—refining a gun so that it shoots better—it's still killing something. And refining the technology so that they can be more accurately messing with something's DNA is still a profound compromise, an invasion… of another organism that is still wrong."	Lammerts Van Bueren et al. (2003); Lammerts Van Bueren (2010); Lammerts van Bueren et al. (2011)
Controlled by corporations	"We have already seen the playbooks of biotechnology companies. Because GMOs are an expensive investment, both in terms of time and money, only the largest biotechnology companies are positioned to research, develop, and test new crops. They benefit enormously as regulatory hurdles are removed." (Cornucopia Institute—SM)	Patel (2009); Jansen (2014)
Raising concerns around intellectual property	"Biotechnology companies hold patents on their seeds, which ensure they retain all rights to the engineered traits. As a result, four seed companies now own more than 60% of the global proprietary seed sales." (Cornucopia Institute—SM)	McAfee (2003); Calvert (2007); Carolan (2008); Stone (2010)
A continuation of industrial agricultural paradigm	"The distinctions between the technologies become less important as you begin to look at the economic and social and cultural impacts… it's often the same approaches, in the area of food, it's around trying to transform food systems … that's about data, that's about food value chains, that's about processing, like all of these kind of things, continuing the pesticide paradigm, but over into genetics, these are all things that are quite in common, and that's because this is, you know it's, an expansion of the industrial approach to food production."	Fitting (2011); Holt-Giménez and Shattuck (2011)
Simply not necessary	"I just don't see the panic in adopting these technologies to make genetic progress. The evidence that I see shows me that the breeding approach that we are using right now is highly effective… And so trying to speak from a position of factual scientific information, the data to me is showing that these technologies are really no better than what we're doing now."	Stone (2002)
Not the 'silver bullet' or panacea it is often treated to be	"Gene editing is not a panacea: New evidence shows that the technology is not nearly as precise or predictable as previously claimed." (National Organic Coalition, "Gene Editing is Prohibited in Organic"—SM)	Scoones (2009)
As successful due to receiving a disproportionate amount of funding (compared with field-based breeding)	"The benefits that [proponents] claim we would get from new gene editing technologies can be achieved through selective breeding. These authentic breeding methods should be funded fully and used to their best advantage to develop cultivars that are resistant to drought, pests, and other organic agricultural concerns." (Cornucopia Institute—SM)	Jacobsen et al. (2013)

(Contd.)

Logics of opposition to gene editing	Example from interviews or synthesis review	Examples of related arguments made about GM
Jeopardizing farmer livelihoods	"...the process of replacing natural commodities with unnatural ones raises significant environmental concerns, and concerns about the impacts on small farmers livelihoods, cultures, and national economies." (ETC Group—SM)	Tripp (2001); Scoones (2002); Soleri et al. (2008); Stone (2010); Schnurr and Mujabi-Mujuzi (2014)
Likely to be opposed by consumers	"Consumers do not want GMO foods: One reason consumers choose to buy organic products is because genetic engineering is not allowed. Any future effort to allow products of genetic engineering into certified organic products will likely be met with the full force of public resistance that the USDA witnessed in 1997, when the organic rules were first written and the initial draft proposal allowed genetic engineering and other now excluded methods." (National Organic Coalition, "Gene Editing is Prohibited in Organic"—SM)	Hughner et al. (2007); Linnhoff et al. (2017)
In conflict with Indigenous rights, protocols, and worldviews on seed	[In paraphrasing the perspective of Indigenous communities the interviewee worked with:] "all this stuff was taken from us originally, and used however they wanted to use it, and we just don't want to go there."	LaDuke (2004); Gugganig (2017); Hoover (2017)
Doesn't address food insecurity or nutrition challenges	"And we know, if you look at the right data sets, that it's the peasant farmers who really feed the world. The large scale industrial crops that are producing way too much canola, sugar and corn that is mostly going into industrial, highly processed non-food products are feeding a fraction of the earth in a way that really nourishes them..... It's a solution in search of a problem."	Tomlinson (2013); Schnurr (2015)

Regarding arguments about the ease and affordability of gene editing, one interviewee perceived these "benefits" as only making it easier for large corporations to diffuse this technology on a large scale. Interviewees were also unsure about the purported benefits of gene editing as more democratic. As one interviewee stated,

> *Accessibility to the technology doesn't mean that it's more democratic—it just means more people are gonna be fiddling around creating risky products.*

In this interviewee's view, enabling farmers to participate in breeding was not a radical idea, but something that is already possible with traditional field-based breeding, as evidenced by existing participatory and farmer-led breeding efforts. As Montenegro de Wit (2020) also finds, interviewees questioned whether farmers would actually have the ability to engage with gene-editing technologies such as CRISPR at all. While proponents have attempted to create an "imaginary" of gene editing as more democratic than GM (Bain et al. 2019), in one interviewee's view, this is a strategy to help large agribusiness avoid the public relations challenges they faced with GM. In both interviews and participant observation, others echoed the sentiment that in marketing gene editing as something separate from GM, proponents are deliberately creating confusion. This has prompted some in the organic community to call for re-articulating and bolstering their previous arguments used in the struggle against GM:

> *It's going to take more sophistication. There is a lot of deliberately muddying the waters, so our arguments need to be that much more sophisticated again.*

Interviewees also expressed that gene editing brings new concerns around traceability and enforceability unlike any previous concerns associated with GM. According to one participant at the COABC conference, the organic community is sometimes viewed as "crazy anti-vaxxers for thinking we have the right to know" about gene editing in the food system. In particular, interviewees emphasized that unlike with GM, there is no test that can be easily performed to ascertain whether a specific organism has undergone gene editing or not. Thus, it may be virtually impossible to determine where gene-edited crops are being grown or sold. They noted that if gene editing is not regulated as GM by either the Canadian or US government, it will be even more difficult to trace.

Some participants shared a broad objection to ownership of seeds, genes, and traits, which they saw as foundational to new genomic technologies, as conflicting with Indigenous worldviews and protocols on seeds as sacred relatives, rather than property or commodities. We are not asserting here that this was a dominant perspective or that the organic community consistently advocates for the interests of Indigenous seed sovereignty movements; however, data from participant observation at the OSA gathering in particular underscored that some members of the organic community employ this logic of opposition in an effort to act in solidarity with Indigenous seedkeepers.

In facing the proposition of gene editing, the organic community is affirming many of the older concerns regarding GM, but doing so in direct response to the new arguments specific to gene editing that proponents are asserting. This "boundary maintenance" involves the ongoing work of bolstering and rearticulating existing boundaries between genetically engineered and organic (Haraway, 1997, p. 67).

4.3. Making it black and white: Closing down debates on gene editing in the organic sector

As shown above, we observed broad opposition to gene editing in the organic sector in this study. However, if we understand the organic community as including a range of boundary organizations with actors situated in and straddling social movements, scientific research, civil society, industrial food enterprises, and government, it is unsurprising that opinions about gene editing vary. We find that the internal and external pressures on the sector has pushed it to narrow its conversations regarding the boundaries between organic breeding and gene editing.

The interviewees who participated in this project were not unanimous in their outright rejection of gene editing. Rather, a minor but notable subset—particularly those involved in the process of plant breeding—expressed curiosity about how gene editing might be used for organic agriculture. It should be noted that all of the individuals supported the exclusion of gene editing from organic agriculture—some quite adamantly so. Despite this, multiple plant breeders expressed some degree of optimism that, with gene editing, biotechnology has the potential to move beyond the "pesticide model" that has dominated with GM crops, where traits serve to perpetuate industrial monocultures with a high dependency on external inputs. These particular interviewees expressed an appreciation of the science involved in gene editing technologies, and the ways that these techniques have been instrumental for their purely scientific (rather than biotechnological) applications—i.e., in helping to better understand how plants work. One participant who bred for both organic and conventional systems was using gene editing to work on a trait related to ease of harvest that had proven tricky to wrangle using other breeding techniques, accepting that any resulting varieties would not be allowed in organic agriculture.

Some expressed their outright ambivalence about the dismissal of gene editing from the organic table. According to one interviewee,

> *With the advent of gene editing, there are definitely some organic farmers, and even seed companies that are very committed to serving organic farmers, who have… really strongly questioned the organic community's resistance to these technologies, understanding by definition that they are excluded, but really… [are] challenging other members of the organic community to better articulate that resistance.*

A few members of the organic community seem to fear that the sector might lose a competitive edge if it does not utilize gene editing. The same interviewee quoted above commented that it was not a common occurrence, but that they "certainly get phone calls" from farmers concerned that organic is "gonna get left behind, if we don't adopt the newest and shiniest technology". These instances further reflect the diverse interests of actors in the organic sector, as well as external pressures to accept the legitimacy of these new genomics-based approaches to plant breeding, or risk falling behind.

Another individual who fully opposed gene editing nevertheless emphasized that having a conversation on gene editing was important:

> *I think it's important to challenge our assumptions, and challenge these positions, as new modern techniques come available, so we're clear as to why we're opposing them… I think that's important, from an ethical perspective as well as from a scientific perspective. Are they safe? And if they are, why that position.*

In other words, despite supporting a strict boundary that excludes gene editing, it was important to this individual that the process of boundary drawing be clear and robust.

Looking back to the history of the organic sector, one interviewee pointed out that a firm oppositional stance against GMOs may have precluded generative debate and discussion about these technologies in the US context. This interviewee commented that prior to 1997, there was "reasoned debate" within the organic community over GM: "[there were] those who were saying 'no, not now', and those who were saying 'no, never' to genetic engineering." But when the USDA proposed to allow GM in organic counter to the recommendations of the NOSB, it brought the organic community together in their opposition of this stance, unifying the community in a way that, according to this interviewee, had never happened before, and hasn't happened since:

> *If the choice was 'yes, now' without any kind of discrimination, without any kind of evaluation and approval process, or 'no, never', we all said 'no, never'.*

Participants in the Canadian context did not describe such a moment. Again, this may be a function of the different trajectories of institutionalization of organic agriculture in the two jurisdictions, as well as the assemblage of organizational bodies that govern them today. In other words, there was no equivalent government authority that could have the power to make such a rule. However, the organic community in Canada has joined forces with allied groups in opposition to GM technology in similar ways, including in the fight against GM wheat and the Arctic apple (Eaton, 2013; Certified Organic Associations of British Columbia, n.d.).

While a strong resistance may seem like a boon to the integrity of the organics label—which depends on consistent and enforceable standards that promote public trust—uniformity of opinion may not always be desirable or beneficial. Has something been lost in the dismissal of more in-depth conversations on gene editing? Some seemed to feel that might be the case. In the words of one respondent, "There's a part of me that's like, who knows what that potential was, and what we missed?" In this view, taking a more deliberative approach to technology might actually do a better job of upholding organic values and principles, noting that some uses of gene editing may be less antithetical than others to organic principles. In the view of this participant, it was very clear that gene editing has the potential to be used in ways that might be compatible with organic. As they explained, a CRISPR-edited crop might be more appealing if it was used, for example, to avoid an input that is acceptable under organic certification:

> *...what if through CRISPR we were able to develop a gene to you know, protect tomatoes through late blight, so now growers don't have to spray copper, which is, you know, which is allowed in organic but is not something we really want in our food! So, I always think about those things, but, knowing that, you know, we still have to draw a line.*

Despite some threads of openness and curiosity about the potential of gene editing, all of the plant breeders we interviewed accepted the legitimacy of the organic sector's position on plant breeding techniques and the need to "draw a line," as stated above. Some gave their own reasons why gene editing was not needed for organic agriculture—such as the importance of breeding for more durable multi-gene resistance to pests and diseases—and another public plant breeder expressed firm conviction that gene editing should under no circumstances be considered under organic agriculture. Others, both in our interviews and participant observation, seemed to imply that making recommendations about what stance the organic community should take was beyond their roles as public plant breeders. In this way, the plant breeders—particularly those at public universities—were negotiating the boundary between the world of institutionalized science and that of the organic movement, and that boundary-drawing sometimes involved accepting conflicting values or worldviews. One public plant breeder agreed with the organic community's rationale that gene editing was part of an industrial agricultural model, but was less comfortable with other logics:

> *Where I have ambivalence is this 'integrity of plants' [concept]. It's a set of values that you have that's outside of science and as a scientist I am not totally comfortable, but, I guess the way I rationalize it is this is what the organic community sees as important, and that's the system I am going to work within.*

The need to meet consumer desires for non-genetically engineered crops was another key reason for opposing gene editing cited by participants in both interviews and participant observation activities. Consumers have a significant, if indirect, role to play in these decisions. As one interviewee noted, "the organic sector is really driven by the regulations which are really driven by consumers," adding that organic farmers are "at the whim of" whatever consumers want. Multiple interviewees associated the focus on excluded methods with the need to cater to the organic consumer base. Unlike the individuals and organic boundary organizations included in this study, who largely viewed organic as supporting a set of political, social, and ecological values (and thus largely oppose biotechnology on similar grounds), the average organic consumer may be less aware of these priorities, and instead purchase organic products for health reasons (Seufert et al., 2017). In fact, one interviewee emphasized that consumers often purchase organic food as a means to ensuring that their food is "clean," "safe," and "pure". Critiquing such a "purity model" of organics, the interviewee explained:

> *There's a subset of organic consumer... who've been kind of believing or told that this is some route to purity. That this is like an ultimate safety, that there's like no chemicals being used, there's no this, no that.*

Another interviewee emphasized the importance of upholding the "integrity" of the organic label, underscoring the need for a consistent message around biotechnology. Yet, the impetus to offer consumers a clearly defined product may be inhibiting more nuanced decisions on these techniques. In another interviewee's view, dependency on consumer preferences forces the sector to rely on binary lines like, "excluded" or "included", rather than more nuanced, open-ended, and inclusive conversations that ask, "what if..."? In this interviewee's view, the emphasis on what is excluded begins to dictate binary distinctions between "good" and "bad" seeds, rather than more context-based judgments.

In summary, our findings reveal some diversity of views on gene editing, particularly for those most engaged in seed and plant breeding—from the desire for more transparency around reasons for exclusion, to curiosity about the technology's potential. Yet, the polarizing legacy of GM debates, rapidly evolving nature of gene-editing technologies, and pressure to communicate a simple message to consumers have pushed the sector to draw a clear line, and the use of gene editing has landed outside of it. Competing pressures—on one hand from proponents of gene editing eager to gain acceptance for the technology, and on the other from consumers who may purchase organic primarily as an assurance of non-GMO—raise the stakes of these internal discussions and boundary-making, pushing the community towards a black-and-white stance where some respondents may have preferred to see gray.

4.4. Opening Pandora's box: New discussions, old breeding techniques

While the use of gene editing in organic plant breeding is firmly agreed to be a closed conversation in the sector, the scrutiny of these boundaries has led to an entirely different discussion on the use of other breeding methods. The review processes employed by the organic community in response to gene editing have also prompted a review of which other breeding techniques should be used to develop varieties for organic production. In other words, discussions around gene editing have opened up a broader project of articulating what transgresses the bounds of organic breeding. Clarifying this boundary is proving to be a problematic task, as many technologies fall into an ambiguous area between what is clearly acceptable and not. While these negotiations involved in this boundary work are playing out differently in the United States and Canada, both jurisdictions face the challenge of drawing boundaries that ensure the integrity of the organic label without causing unnecessary upheaval by excluding cultivars that are already widely used by organic farmers. We find that this ambiguity is prompting difficult ontological questions that challenge the sector to more fully articulate and even redefine its understanding of what constitutes acceptable forms of human intervention in nature.

In the United States, as part of the development of its Excluded Methods list, the NOSB has begun to review both other new methods and also those that have been around for much longer—some of which may already have been used to develop traits that are now in organic seeds. Since the establishment of the Excluded Methods list in 2016, several additional methods have been added to it beyond gene editing, such as the use of transposons developed using in vitro nucleic acid techniques.[5] As well, some methods have since been decided as allowable in organic breeding, namely, marker-assisted selection, transduction, and embryo rescue in plants. The methods still awaiting decision are listed below in **Table 6**.

While we did not find documentation of such a formal process in Canada, interviewees confirmed that similar discussions are unfolding regarding excluded methods in the Canadian organic standards (and are reflected in the draft definition of genetic engineering in **Table 2**).

At the root of these new clarifications is the sector's need to articulate a difference between gene-edited seeds, and those produced using irradiation- or chemical-based mutagenesis. These latter techniques have existed for nearly 100 years and, according to multiple interviewees, have been used to develop many traits present in varieties cultivated widely in organic agriculture today. These forms of mutagenesis are not regulated as biotechnology in the United States. Canada does not regulate food safety based on use of biotechnology but rather novelty of traits; thus, specific techniques, such as induced mutagenesis, or gene editing, are not specifically regulated in Canada. As discussed above, gene-edited seeds are often indistinguishable from seeds produced using older forms of mutagenesis, and so present similar challenges to transparency for farmers who may want (or need) to avoid varieties developed using these technologies. Indeed, proponents of gene editing have argued that it is not so different from older forms of induced (random or semi-random) mutagenesis. While organic respondents have attempted to contest this claim, it has been a difficult one to dismiss. According to a Canadian interviewee, "if mutagenesis was being invented today, it would probably have been prohibited." Yet, due to the sector's widespread use of crops with mutagenic parentage, this interviewee felt that the "horse is out of the corral," and that at this point it would be very problematic to exclude induced mutagenesis as a technique. Interviewees from the United States echoed this sentiment. The sector's attempts to distinguish the two techniques have prompted the question: what justifies this boundary?

Globally, national biosafety regulatory bodies are grappling with similar questions of how to re-draw boundaries in light of gene-editing techniques and their apparent similarity to such approved techniques. Regarding the use of gene editing in agriculture, the European Union—historically conservative in this domain—asserted in 2018 that gene editing is not allowed, but that induced mutagenesis is indeed acceptable due to its long history of safe use (Court of Justice of the European Union, 2018).

Decisions about which methods to exclude are not just theoretical or hypothetical: these boundaries are practical necessities that have real implications for organic producers, consumers and the organic market. Of the methods being debated, some were used to develop traits that are currently present in varieties widely used in the sector. For example, multiple interviewees discussed the case of plants in the Brassica genus, in which many important varieties used in organic production have been bred using cell fusion. If cell fusion were to be strictly excluded, whether immediately or with a sunset clause, this would effectively eliminate nearly all broccoli from organic certification.

One participant also noted that organic farmers themselves want the organic sector to draw clear lines of acceptability, and that one of the roles of effective and objectively "good" standards is to make things—in this case, acceptable breeding methods—black and white. However, the technical nuances and varied applications of breeding techniques make it difficult to easily navigate acceptability. For example, the subtleties and particular ways in which a method is used can determine its potential acceptability. As one breeder explained, while there is a tendency to view the method protoplast cell intrusion as analogous to another, cytoplasmic male sterility, these two

Table 6: Breeding methods awaiting decision as of October 2019 (National Organic Standards Board 2019). DOI: https://doi.org/10.1525/elementa.429.t6

- Protoplast fusion
- Cell fusion within plant family
- TILLING/eco-TILLING
- Induced mutagenesis, developed through exposure to UV light, chemicals, irradiation
- Doubled Haploid Technology
- Transposons
- Embryo transfer or embryo rescue in animals

techniques are not necessarily used in the same way. While drawing the boundaries to exclude the use of gene-editing technologies in the sector appears to have strengthened the integrity of the organic label by responding to public pressure, there is considerably less external pressure, awareness, and polarization around these other breeding technologies. Yet, decisions to exclude these methods will significantly limit the range of varietals of which the sector can avail itself as those bred using cell fusion and similar techniques are disallowed in organic farming. Many in the community are aware of the resulting economic impacts, but also aware of the tension between these techniques and upholding organic values in the breeding process, and thus organic integrity.

Several participants noted the internal contradiction inherent in accepting older breeding methods like mutagenesis while rejecting newer genomic techniques, and the reputational risks that it presents. One interviewee cited the importance of not getting caught "asleep at the wheel", explaining that the sector would lose legitimacy in the eyes of consumers if, in a "worst case scenario," a technique currently being used widely was found to be at odds with organic principles. Breeders would have to admit to growers that they would no longer be able to use a variety they had long been relying on because "nobody was paying attention". This boundary work involves important negotiations around what is practical for farmers, reflects the foundational values of the movement, responds to external pressures, and maintains long-term integrity of the sector. Despite the challenges of this boundary work, interviewees were generally in agreement about the need to clarify the acceptable vs. unacceptable methods for the sector. One interviewee commented, "In order for organic to be organic, we have to draw a circle around organic… you can't have it all be grey, because otherwise organic is not organic."

Despite generally sharing this sense of the need to draw such a circle to protect organic integrity, not everyone agrees on where the line should be drawn. This boundary drawing may also be exposing some of the fault-lines in the community, such as around the importance of holism and the integrity of cell wall, as noted above in our discussion of the diversity of views around gene editing. Discussions of the acceptability of marker-assisted selection (MAS) are also emblematic of these divergences. MAS involves the use of genomic markers to assist in the breeding process. Although the prevailing view was that MAS is an important tool that organic agriculture should make use of, some viewed the technique as part of a broader technification agenda. One interviewee commented that they were aware that people have been "lumping" MAS with other techniques that involve the modification of the genome. Another interviewee commented that they were aware of a subset of the sector that subscribes to a more holistic philosophy inspired by biodynamic farming, and did not support MAS on the basis that it is incompatible with this set of values. Several interviewees expressed the specific concern that, similarly to concerns with gene editing, such lab-based techniques are inherently exclusionary, as they lend themselves to use and control by corporations.

The concept of naturalness also presents a troublesome concept in boundary-making because of its vagueness and potential for multiple interpretations. The idea of naturalness is built into the discourse on acceptable breeding techniques: The Canadian Committee on Organic Agriculture says that something is genetically engineered if the genetic material of an organism is changed in ways that do not involve "traditional breeding by multiplication and/or natural recombination" (**Table 2**), and it notes that techniques that are not included in this definition are those that involve "conjugation, transduction, transformation, or any other natural processes." Similarly, the NOP's definition of breeding methods that are excluded from organic production is those methods that are "not possible under natural conditions or processes" (Section 4.1).

Different actors may interpret the "natural" boundary differently, particularly in the face of growing technical complexity. Some interviewees feel the boundary that has been drawn between different types of breeding is already somewhat arbitrary: if organic breeding values the reliance on natural processes (following US and Canadian guidelines), and breeding often involves speeding up these natural processes, what is too fast? Multiple interviewees grappled with these questions and expressed ambivalence about how to make such distinctions. Reflecting on the distinction between genetic engineering and more natural breeding methods, one interviewee noted that the same types of physical changes differ in their acceptability, depending on the extent of human intervention in the process:

> *If you notice a mutant in the field, that mutated spontaneously or maybe in response to ultraviolet radiation, or something like that, that's totally fine, nobody opposes that…. But if you go and start shooting that plant with X-rays or gamma rays, it's basically the same thing, a mutation is happening, but you're causing it to happen in a way that is not quite natural… Then you talk about transposons, which are genes that kind of jump around the genome, and they can land in another gene and disrupt it, and cause a big change to that plant, and if that transposon happens to jump, because it was just a spontaneous event, that's totally fine.*

As the interviewee continued to speak, their ambivalence surfaced more visibly:

> *If you subject the plant to salt stress, well is that ok? How about if you expose it to a synthetic chemical, that induces the gene to jump, is that ok? … And there's another way you can get a transposon to jump, and that's to introduce some nucleotide sequences and so [the NOSB has] said… it's all the same process, but if you induce it to happen using a nucleotide sequence, it's banned, if you induce it using some kind of natural thing like salt it's allowed, and if you expose it to something like chemicals, that's currently under review.*

This interviewee attempts to pin down their intuitions around what constitutes an acceptable level of intervention in the breeding process; "organic values"—such as those articulated by IFOAM's four principles—do not map in an obvious way onto the decision about which techniques are acceptable and which are not. Boundary work around organic breeding is thus forcing the organic sector to operationalize its core values, and as such, efforts to clarify these boundaries result in tensions about what it means to breed plants and develop traits in an organic way.

4.5. Navigating barriers to inclusive boundary work on biotechnology

In the preceding sections we have described the organic community's ongoing negotiations to scrutinize, bolster, and in some cases redefine, boundaries around acceptable approaches to organic plant breeding. Here we argue that debates about gene editing and organic breeding may be bounding out important actors from deliberation processes, and thus prioritizing some voices over others. We highlight barriers to more inclusive participation in these debates, and note initial signs that some in the organic community are attempting to reckon not only with the exclusive nature of decision-making around organic breeding, but oppressive dynamics around plant genetics and seed systems more broadly.

Sociologists and science and technology studies (STS) scholars have long argued that there is a need for more open discussion in public arenas about questions of responsibility, risks and ethics in relation to biotechnology (Levidow and Carr, 1997; Wilkins et al., 2001; McCullum et al., 2003). Echoing these concerns for more accessible fora to discuss these questions, our interviewees noted several ways that these discussions are excluding many actors in the sector—particularly farmers—from participating in these discussions due to a lack of time, resources, energy or knowledge needed to wrestle with the complex issues that new gene editing technologies raise. Participants involved in standard-setting activities with the NOSB (United States) and the Technical Committee (Canada) emphasized the large amounts of time and resources that this boundary work entails. During the session on gene editing at the COABC conference, one participant from the Technical Committee who was involved with re-writing the definition of genetic engineering used in the Canadian Organic Standards lamented about the immense workload this involved, calling it a "nightmare", and reflecting that defining these terms "has become so complex".

Indeed, our findings suggest that the heavy burden involved in navigating this complex, dynamic landscape of breeding technologies seems to be preventing many from participating. Not everyone in the sector has the capacity or even the interest to participate in these policy discussions. One breeder noted that amongst farmers they worked with, concerns around new technologies simply were not on the top of their priority list, given the numerous other challenges that they confront on a daily basis:

> *They don't want GMOs, of course, but with some of these new technologies, it's just not something that's forefront on their mind. They're thinking, how do I keep this crop healthy? How do I get good yields? How do I keep my farm alive? How do I maintain the soil?*

Based on this perspective, there is a case to be made here for a smaller number of "knowledgeable experts" to take the lead on decision-making. However, a small but vocal number of interviewees were concerned that the hierarchical approach to decision-making and limited participation from the larger organic community was problematic. One interviewee expressed discomfort with the centralized process by which the NOSB is aiming to resolve these nuanced questions, noting:

> *I don't like the idea that there's like five smart people in a room somewhere that have determined that 'in all cases, this is the case.'*

This participant expressed a desire for this decision-making process about excluded methods to be slower, more transparent, and more inclusive of different perspectives.

One of the challenges in making deliberation over breeding methods more inclusive is their invisibility: you cannot discern how a plant was bred just by looking at it. As Lammerts Van Bueren et al. (2003) discuss, agricultural biotechnologies can be insidious because of the way that both their nature, as well as the intentions of the companies using them, are hidden from view. One of the farmers we spoke with commented that it is very difficult for producers like them to determine whether they are buying seeds that are allowed in organic production, as the information on breeding methods used to develop a given variety is often not disclosed. This interviewee recalled a farmer getting in trouble from a certification body for using a seed mix that had been developed using an excluded method, but as that mix was proprietary, there was no information on the product that would allow the producer to know what they were buying. The farmer emphasized that the seed may have been farmed according to organic principles and standards, but they still may not be able to sell their crop as organic if the breeding method is not acceptable under organic standards. Several interviewees noted similar concerns around proprietary information, highlighting how corporate interests can prevent farmers' understanding of their own production systems or the methods used to develop the very plants they cultivate.

The processes involved in delineating acceptable breeding technologies may have thus excluded some actors from the organic community by largely occurring behind closed doors, despite ongoing work on engagement by OSA in the United States, as well as public comment periods to the NOSB and the Canadian Committee on Organic Agriculture. The complexity and invisibility of these techniques create further barriers to more inclusive participation in decision-making processes. It is worth noting that concerns about exclusive decision-making by technical experts were more pronounced in the US than the Canadian context. As outlined in section 4.1, the relative size, composition and procedures of the Technical Committee suggest a more democratic and inclusive approach overall. Its 40 elected members (half of which are farmers) represent larger groups or organizations, with only 5,791 organic producers in the country. The NOSB has less than half as many committee members (15) despite representing a sector more than three times the size (18,166 producers) (Willer et al., 2020), and holds relatively less decision-making authority than the Technical Committee in Canada. These governance differences notwithstanding, participants in both jurisdictions shared concerns about the burden of understanding required to participate in boundary work on breeding methods, as well as the obfuscation of these methods by corporations. Without capacity-building processes to equip farmers and non-breeders with the requisite knowledge for participation, these discussions risk excluding all but committee members and technical experts.

Boundaries are inherently about what is bounded out, but they are also about what is bounded in. If the organic community can create spaces to more inclusively negotiate the tensions that arise at its edges, it may demonstrate ways that boundary-making can be generative in defining relationships and shared goals in support of solidarity. We see an example of this in organizing by Organic Seed Alliance to add a "Seed Ethics Track" to its 2020 Organic Seed Growers Conference. This track, which intentionally centered speakers from racialized and marginalized communities, focused on facilitating better understanding between the organic seed movement, and "those who may not consider themselves part of either [the organic farming or organic seed] movement, and instead align themselves and their practice with related movements or currents, including agroecology, Afro-ecology, Indigenous, regenerative, permaculture, biodynamic, agroforestry, anti-GMO, open source seed, and others" (Hubbard, 2020). Interactions in this track revealed both emerging solidarities and uncomfortable tensions as speakers and attendees unpacked, for example, tensions between Indigenous worldviews that rejected ownership of seeds, and organic plant breeders using patents to fund their work.

These conversations are clearly just beginning, and involved stumbles and missteps as well as revelations. Yet, if carried forward they may exemplify a way in which better, more inclusive boundary-making could help guide those working at the boundary of science, policy and practice of organic plant breeding. Whose conceptualization of seed is valorized, and whose breeding methods are accepted and promoted? How might the organic sector and organic breeding be perpetuating the legacies of colonialism and biopiracy? How do these divisions impact who is included at the decision-making table? Or alternatively, how might better alliance-building at the boundary help the sector negotiate tensions between organic values, integrity, and economic success that have been stirred up by new developments in gene-editing technologies? As the organic community continues to negotiate its stance towards other breeding methods, these conversations will likely continue to challenge the community with inclusive, discursive decision-making, but opportunities are also arising for the sector to bound "in", and to re-orient the conversation around what organic stands for and who it stands with, rather than against.

5. Conclusion

We have argued that the advent of new gene-editing technologies is prompting the organic sector to both reinforce and deepen existing boundaries between organic breeding and biotechnology, dampening some conversations and narrowing the debate around these boundaries where the integrity of the sector seems to be stake, and prompting reconsideration of boundaries relevant to organic breeding more broadly. The processes of boundary-making captured above also illustrate the reality that defining boundaries will necessarily include some actors and exclude others. Despite inherent barriers to more inclusive and democratic decision-making about breeding technologies in organic agriculture, we have concluded with an illustration of how the organic community could use boundary work as an opportunity to build new alliances, and to bound in actors with synergistic visions for what organic breeding and seed systems could look like.

Boundaries are necessary for the ongoing integrity of the organic sector, yet the act of drawing them carries its own complications. Deciding on accepted and excluded breeding methods has significant implications for the sector, as these decisions have the potential to perpetuate internal contradictions in the organic standards or limit the range of varieties organic farmers can use. The process of engaging in renewed scrutiny of boundaries is creating spaces for the organic community to grapple with operationalizing values-based principles and protecting organic integrity. In this process, both internal and external pressures tend to center concerns about what organic *is not*. The challenge for this multi-faceted community in the face of ongoing technological development will be to engage in generative boundary work that articulates what organic *is*, and a vision for what it *could be.*

Data accessibility statement

The interview protocol has been submitted as a supplementary material. We cannot provide transcripts for reasons of confidentiality.

Abbreviations

BC: British Columbia
CBAN: Canadian Biotechnology Action Network
CGSB: Canadian General Standards Board
COABC: Certified Organic Associations of British Columbia
CRISPR-Cas9: clustered randomly interspaced palindromic repeats and CRISPR-associated protein 9
FiBL: Research Institute of Organic Agriculture
GM: Genetically modified
GMO: Genetically modified organism
IFOAM: International Federation of Organic Agriculture Movements
NOP: National Organic Program (US)
NOSB: National Organic Standards Bureau (US)
OSA: Organic Seed Alliance
OSGATA: Organic Seed Growers and Trade Association
OSGC: Organic Seed Growers Conference
STS: Science and technology studies
US: United States
USDA: United States Department of Agriculture

Notes

[1] Because the Canadian approach to biosafety focuses on the novelty of traits included in the final product, rather than the techniques used, gene-edited crops do not necessarily represent deviations from the status quo for the Canadian Food Inspection Agency, Canada's relevant authority (Eckerstorfer et al., 2019).

[2] While there are many valid debates/criticisms of the terminology used to describe, regulate, or provoke desired responses with regards to these technologies, a detailed engagement with terminology is beyond the scope of this paper.

[3] It is outside the scope of this paper to delve further into the full scope of debates on GM.

[4] Although other kinds of techniques and technological approaches are part of this next wave of biotechnology, such as synthetic biology and gene drives, our focus in this paper is on gene editing, as it is the most developed of these and has received the most complete set of responses from the organic community.

[5] However, transposons developed in other ways are still on the "to be determined" list.

Supplemental files

The supplemental files for this article can be found as follows:

- **Narrative synthesis.** Spreadsheet of documents reviewed pertaining to gene editing and the organic sector. DOI: https://doi.org/10.1525/elementa.429.s1
- **Interview protocol.** Protocol used for semi-structured interviews. DOI: https://doi.org/10.1525/elementa.429.s2

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The authors have no competing interests to declare.

Author contributions

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- Contributed to acquisition of data: SN, SK, AL
- Contributed to analysis and interpretation of data: SN, SK, AL
- Drafted and/or revised the article: SN, SK, AL
- Approved the submitted version for publication: SN, SK, AL

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