

PRACTICE BRIDGE

Can public universities play a role in fostering seed sovereignty?

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Across Canada and the United States, public universities were founded with a mission to contribute to broad societal well-being. Yet, the capacity of public research institutions to develop and disseminate flexible and accessible tools for resilient agriculture has been challenged in recent decades. The role of universities in advancing extractive, rather than regenerative, economies has been amplified by the privatization of public agricultural research and extension of knowledge to farmers, particularly in plant breeding and plant genetics. In this article, we examine the history of public research for seed systems in North America through a “seed regimes” framework, arguing that a narrow focus on commercialization of public research has exacerbated inequalities inherent in the founding structure of public agricultural research, including the displacement of Indigenous land and seed relations. We then discuss how community organizations are challenging the enclosure of seed through seed sovereignty organizing and freelance plant breeding, in some cases through the development of community–university partnerships based on the principles of the cocreation of knowledge. We conclude by offering a reimagined public seed research agenda that focuses on strengthening links between public research and grassroots seed movements, as an opportunity to build more resilient seed and food systems.

Keywords: Seed sovereignty, Commons, Public research, Plant breeding, Seed regimes, Community-based research

Introduction

Over the last century, corporate concentration in the seed sector and stringent intellectual property rules related to the dissemination of seeds and cultivars have eroded farmers’ ability to “choose what to grow, how to grow it, and for whom” (IPES-Food, 2017, p. 5). Montenegro de Wit (2017a) describes this as the enclosure of seed: the incremental transformation of plant genetic resources from a common good—free for particular communities to save, share, and sell—to private property concentrated in fewer and fewer hands. This enclosure of seed has been driven not only by seed industry concentration but also by the related privatization of public plant breeding and seed research. The intertwined public- and private-sector processes of seed enclosure have also led to an erosion of crop biodiversity (Bioversity International, 2017), constraints on farmers’ and communities’ resilience to shocks such as climate change (Kotsohi and von Lossau, 2011), and

negative impacts on community health and heritage tied to nutritionally and culturally important varieties (Fanzo et al., 2013).

In response to these developments, community seed activism has emerged in both the Global South and North to maintain and restore diverse and culturally important cultivars, challenge the enclosure of seeds, and assert farmers’ and peasants’ rights to seed sovereignty. In the United States and Canada, community seed movements—particularly associated with the organic seed sector—have built alliances with public universities and mobilized for increasing public investment in plant breeding and cultivar development for organic and ecological agriculture. These efforts have been successful in increasing plant breeding and graduate student training activities for organic seed systems but still play a minor role in public research. As such, questions have emerged from global seed movements about whether, and to what extent, public research can be revitalized to play a more transformative role in reopening seed enclosures, despite a series of institutional lock-ins to a privatized model of cultivar development.

In this article, we examine how and whether public agricultural research can contribute to transforming seed systems from privatized enclosures to a “seed commons,” a set of collectively managed resources governed by a set of rules enabling protection and regeneration of

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a particular set of resources (Ostrom, 1990). In this case, we view a revitalized seed commons as necessary foundation of resilient and community-led agricultural systems. Focusing on Canada and the United States, we argue that this question requires consideration of both the history of privatization of seed and plant breeding and the colonial roots of public agricultural research. We present a historical policy analysis of public plant breeding and seed research in the United States and Canada and its implications for both university researchers and community seed activists. We first conceptualize the evolution of a public seed research paradigm through the frameworks of *seed regimes* and *academic capitalism*. We highlight Indigenous and Black histories in constituting the first seed regime and in resisting the third. Finally, we argue that despite ongoing disinvestment from public plant breeding and the constraints of other institutional lock-ins, university researchers can and should find new ways to support the emergence of more resilient and equitable seed systems by engaging with community seed movements. We draw on our experience from 5 years of participatory action research with community seed networks in Canada, as well as embedded fieldwork as organizers of participatory plant breeding networks in the United States, to offer insights on the opportunities and barriers for university engagement with community seed networks.

We employ the theoretical framework of *seed regimes*, based on Devlin Kuyek's (2007) adaptation of Harriet Friedmann and Philip McMichael's *food regimes* concept (1989), to understand the role of universities in developing, regulating, and transforming seed systems through time. Both food regimes and seed regimes are conceptualized as "a period of relatively stable relationships, governed by regulations and norms, and bordered by crises in which new possibilities emerge" (Kuyek, 2007, p. 31). Importantly, tensions and instability that develop in each seed regime lay the groundwork for the shifts into the next regime, and so the boundaries between regimes are blurred and remnants of former regimes may be observed in the current one.

We also explore the concept of *academic capitalism* to understand the transformation of public research in the 20th and early 21st centuries. Critiques of contemporary public agricultural research problematize the idea of a purely beneficial public science, identifying a shift in the land grant university system toward what has been called an "academic capitalism," that is, a knowledge/learning regime dominated by private corporations, which exists alongside and sometimes replaces the older "public good" knowledge/learning regime (Slaughter and Leslie, 1997; Slaughter and Rhoades, 2004). The academic capitalism framework describes how universities adapt to the global knowledge economy, in which knowledge is a new raw material, by fostering networks that link faculty, students, and administrations to the private sector. In this view, academic capitalism is a logical adaptation by universities to the ascendant neoliberal political order that emphasizes "privatization, commercialization, deregulation, and reregulation" (Slaughter and Rhoades, 2004, p. 18).

Seed regimes in North America: From Indigenous seeds to public investment to corporate capture

Seed systems in North America and throughout the world owe much of their present-day diversity to Indigenous peoples who have created and stewarded diverse crop varieties for thousands of years, including initial domestication (Mueller, 2018), intentional hybridization with crop wild relatives (Nabhan, 1989), and local and long-distance exchange (Boyd and Surette, 2010). Colonial dispossession and displacement of Indigenous people was accompanied by the disruption of agricultural practices and foodways, and replacement by crops highly utilized by Europeans, such as wheat. Yet Indigenous seedkeepers preserved and maintained seeds such as corn, beans, squash, tobacco, and other crops in the face of extreme hardship and displacement from land (Gwin, 2019; White, 2019). Indigenous people also exchanged seeds with early settlers, whose European crops were poorly adapted to the conditions of North America and who survived in part by adopting/appropriating Indigenous crops (Kuyek, 2007).

As European colonization expanded across North America, settler farmers established what Kuyek (2007) identifies as the first of three seed regimes, a new set of "relationships, norms and regulations" which organized the increasing commodification and enclosure of seed through periods of capitalist accumulation. In Canada and the United States, the first seed regime was marked by innovation and knowledge exchange that was largely autonomous from the state, as settler farmers used local experimentation and decision making to adapt European and Indigenous seeds to their needs. The chronology of the first seed regime differs between the Canada and the United States, as the early colonialist agriculture in the United States was already focused on the production of exports, while Canadian agriculture at the time was primarily for the subsistence needs of settlers within a mercantile system based on fur exports. U.S. state support for agriculture began in 1820 in the form of organized plant introductions and developed into a massive distribution of free seeds of hundreds of cultivars including flowers, vegetables, corn, and cotton to farmers from 1860 to 1900. It was not until 1895 that the Canadian Parliament commissioned William Saunders to develop similar projects, including a free seed distribution system starting in 1895 and the first experimental stations starting in 1905 (Griesbach, 2013). In the United States, this period was also characterized by seed systems developed within the context of the slavery-based plantation system. Enslaved Africans transported seeds such as rice, sorghum, millet, cowpea, castor bean, and many others across the Atlantic Ocean and applied their own agricultural expertise to adapt them to new climates, sometimes for their own sustenance and sometimes at the behest of their enslavers, both as commodity and as survival food (Carney, 2013; Twitty, 2017; Keeve, 2020). These histories—of settler appropriation of Indigenous lands and seeds and of seed exchanges in the context of slavery—must be acknowledged in discussing the first seed regime and are at the forefront of our understanding of how future seed

commons might emerge that respect intellectual and cultural rights and center equity and justice.

State intervention to develop public seed research was the key feature of the second seed regime in North America, which arose with public investment and early regulation of seed systems as a matter of perceived national interest. This process began in the mid-19th century with the advent of public agricultural universities and became fully manifested in public investment in the development of hybrid technology in the early 20th century. What Kuyek describes as the second seed regime aligns with what Slaughter and colleagues conceptualize as the “public good” knowledge/learning regime (Slaughter and Leslie, 1997; Metcalfe, 2010). The public good regime identifies a strategic role for public universities to advance the industrial economy through disciplines concerned with “science-based mass production industries and states’ ground rules for capitalism” (Slaughter and Rhoades, 2004, p. 15). In the United States, agricultural experiment stations and colleges of agriculture were founded by the Morrill Act of 1862, which funded a system of public “land grant” universities via the expropriation of Indigenous territory, and the Hatch Act of 1887, which funded agricultural experiment stations under the direction of these universities (Buttel and Busch, 1988). The Canadian Parliament commissioned a report in 1885 on the American system of experimental farms, resulting in the formation of Canadian agricultural experiment stations from 1886 through 1916. These were public institutions, though not as directly linked to public universities as in the U.S. land grant system (Kuyek, 2007; Jones, 2013). Another key piece of public investment in agricultural research in the second seed regime in the United States was the Cooperative Extension Service, formalized in 1914 through the Smith–Lever Act to ensure access to the insights of the agricultural sciences for farmers and, at least in theory, broader publics (Mcdowell, 2003; Goldstein et al., 2019). Extension as a nationally coordinated cooperation between universities and the government never emerged in the same way in Canada; rather, provincial governments cooperated with voluntary and commodity-specific groups to provide agricultural education in the second seed regime, formalized by the Canadian Agricultural Education Act of 1913 which provided for the appointment of extension agents as part of provincial government services (Gill, 1996).

The initiation of public agricultural research in North America was deeply tied to the settler colonial projects of the first seed regime (Ammons et al., 2018). As Lee et al. (2020) have extensively documented, the Morrill Act was funded by violent dispossession of nearly 11 million acres of land from Indigenous people. The research and extension services that this public system provided were also designed around ensuring the success of settler farmers on recently dispossessed land. For example, a strong impetus for the creation of the agricultural experiment station network in Canada was the need to breed early-maturing wheat varieties that would aid settler expansion in the Canadian prairies (DePauw et al., 1995; White, 1995). In the 20th century, this focus shifted toward boosting

extensive commodity production of selected field crops to feed the populations of growing cities, develop export markets, and bolster Canada, the United States, and their allies during World Wars I and II (Cronon, 1992; Friedman, 2000). New regulations such as the Seeds Act of 1923 in Canada and the Federal Seed Act of 1939 in the United States regulated the naming of varieties and quality of seeds in order to protect farmers from false advertising. This established a precedent for state regulation of seed which would eventually form the basis of seed enclosures in the third regime. In the 1920s, the increased production of commercial hybrids by emerging corporations introduced a biological means of enclosure. Hybrids, which were based on new breeding techniques developed by public research programs, produced seeds that farmers had to purchase anew each year in order to maintain productivity (Kloppenburg, 2004). In Canada, Kuyek (2007) observes, there was “little controversy” over the transition “from farmer-to-farmer seed exchanges to top-down technology transfers [that] involved a critical shift in power from farmers to the state” (p. 38).

The second seed regime, with its emphasis on state-supported research for higher yields, benefited a relatively small group of “early adopting” farmers but also had negative impacts for agricultural livelihoods and rural economies as a whole. This was because higher yields, and the high-priced technology and seed required to achieve them, set up a technology treadmill which led to chronic oversupply and thus to lower prices (Buttel and Busch, 1988; Lowe et al., 1993). Another hallmark of the second seed regime were High Yielding Varieties, the Green Revolution cultivars developed by public research programs and introduced in the Global South beginning in the 1960s (Kloppenburg, 2004). Although the Green Revolution plant breeding paradigm increased yields of key grain crops and boosted overall production, it drew both contemporary and retrospective criticism for eroding crop diversity, increasing pesticide use and exacerbating social inequality (Lipton and Longhurst, 1989; Harwood, 2019). This paradigm of agriculture is now critiqued as “extractivism,” extending the 1930s understanding of “soil mining” in the Great Plains that led to depletion and pollution of soils and waters in monocultural agriculture (Kumar, 2016).

The beginning of a third seed regime can be associated roughly with the advent of genetic engineering in the 1970s and a series of legal developments that established intellectual property protection for seeds, setting the stage for increasing privatization of public seed research and development established in the second seed regime. The founding of public agricultural research under the second seed regime privileged White farmer/settlers and affirmed the role of agricultural research in “controlling” the environment rather than working with nature. Ongoing privatization trends under the third seed regime intensified the appropriation of public knowledge creation. In the United States, these included the Plant Variety Protection Act (PVPA) of 1970 which established the protection of new varieties of sexually reproduced plants with a 17-year Plant Variety Protection certificate, allowing the owner to

exclude others from reproducing the variety for commercial sale but maintaining farmers' and researchers' right to save seed. In 1994—even though the United States did not sign the international agreement that became the primary international framework for the governance of intellectual property rights over seeds—the PVPA was updated to align with the 1991 Convention of the International Union for the Protection of New Varieties of Plants (UPOV). The U.S. utility patent system emerged in 1980 following the U.S. Supreme Court decision on the patentability of living organisms in *Diamond v. Chakrabarty*, extended to plants in 1985 (Luby et al., 2015). In Canada, the Plant Breeders' Rights Act, which established similar protections to the PVPA in the United States, was not adopted until 1991. After much controversy, it was updated in 2015 to align with UPOV, which Canada ratified that year. The third seed regime has also seen the advent of a series of international agreements beyond UPOV, such as the World Trade Organization's Trade-Related Intellectual Property Rights Agreement (1996) which, along with other agreements, establishes a broad and sometimes contradictory framework of intellectual property rights that have been essential to the development and elaboration of a privatized biotechnology sector (Zerbe, 2015).

If the second seed regime introduced seed enclosures in the name of a national interest, the third regime strengthened and expanded those enclosures in the name of transferring seed research, knowledge, and development from the public to the private sector. The shift from the second to the third seed regime aligns with a shift in knowledge/learning regimes from seeing education as a public good, to a framework characterized by academic capitalism when public research gave way to privatization as the shaping force of knowledge and social relations around seed. Privatization of agricultural research, particularly in the areas of plant breeding and biotechnology, was a keystone in the broader reshaping of public sphere higher education in response to global economic trends in the late 20th and early 21st centuries (Slaughter and Leslie, 1997; Slaughter and Rhoades, 2004). Although genetic engineering was discovered and developed at public universities, its initial commercialization was carried out by small technological start-ups backed by venture capital (Kloppenborg, 2004; Bjornstad, 2016). The start-ups that initiated private investment in plant breeding were subsequently acquired, along with their intellectual property and protected germplasm, by multinational agricultural companies that began to enter the seed sector in the 1980s and 1990s (Howard, 2015). By making development of proprietary varieties more profitable, consolidation further incentivized privatization of cultivar development (Heisey et al., 2002). Consequently, global private investment outpaced public investment in agricultural research and development in Organization for Economic Cooperation and Development countries from 1985 to 2015, and private spending accounted for nearly half of agricultural research spending by 2013 (Pray and Fuglie, 2015; Jaruzelski and Johnson, 2017). Private spending on agricultural research and development has also

become concentrated among the largest firms due to acquisitions and mergers (IPES-Food, 2017; Clapp, 2019).

Lock-ins and enclosures in the third seed regime

Vanloqueren and Baret (2009) show how technological lock-ins within agricultural research favor a reductionist paradigm that emphasizes (1) a small number of export-oriented crops, (2) yield as a primary or even sole breeding target, and (3) use of inputs to create uniform growing environments. Lock-ins to this paradigm hamper the development of more diverse agricultural pathways, despite calls from internationally recognized scientific assessment panels for greater support for public sector investment and a shift toward research agendas combining farmer and scientific knowledge guided by social and ecological goals as well as food security (IAASTD, 2009).

The contemporary (third) seed regime, which favors development and release of new seed varieties under patent or royalty agreements, constrains efforts to contribute to a new seed commons (Montenegro de Wit, 2017a; Hecquet et al., 2018). Public plant breeding in the United States has been in decline since the 1980s when state legislatures and university administrations began to cut funding for cultivar development and declined to hire new plant breeders to replace retiring faculty, shifting responsibility for cultivar development to the private sphere (Frey, 1996; Knight, 2003; Shelton and Tracy, 2017). The passage of the U.S. Bayh-Dole Act in 1980 allowed universities “to own inventions resulting from federally sponsored research and to exclusively license those inventions” (Boettiger and Bennett, 2006, p. 320), creating incentives for university technology transfer agencies (TTAs) to reserve the first right to develop patents or licensing on new lines and cultivars developed by faculty plant breeders (Slaughter and Rhoades, 2004; Luby et al., 2015). This reduced the ability of public plant breeders, and any farmers they collaborate with, to determine how or even *if* newly developed cultivars are released. For example, varieties developed through participatory plant breeding, which would most appropriately be released in a way determined collaboratively by the farmer and plant breeder, can only be released in the way that is determined by the university's TTA (Shelton and Tracy, 2015).

The United States lost 31% of its public cultivar development programs between 1993 and 2013, causing concern about the ability of public plant breeding infrastructure to carry out long-term research to address complex and emerging problems such as disease resistance and drought tolerance (Carter et al., 2014). In Canada, a combination of government deficits and commitments to international trade agreements in the 1980s and 1990s led to a reduction of the federal budget for agricultural research by 20%, not only reducing support for agricultural extension facilities but also shifting some public funding into grants for private-sector research (Klein, 2001; Metcalfe, 2010).

In addition to tying public plant breeding to seed enclosures, the reduction of funds for public seed research has shifted agricultural research agendas. It more deeply channels the historical legacies of the first and second seed regimes toward a paradigm emphasizing high yields and a narrow range of commodity crops that offer the highest return on investment for private-sector breeding programs. Private plant breeding agendas in the third seed regime emphasize crops such as soy and corn that are closely linked to the agro-industrial complex both through paired inputs sold by the same companies (e.g., herbicide-tolerant seeds) and through the pursuit of competitive advantage through control over intellectual property (Heisey et al., 2001; Lianos and Katalevsky, 2017). By shifting power and investment from the public to the private sector, the third seed regime has embraced a corporate research agenda within publicly funded research.

Public-sector investment is critical for crops that experience underinvestment from the private sector, including culturally and nutritionally important vegetable crops as well as staples such as legumes, grains like millet, sorghum, and quinoa, and tropical tubers such as cassava—sometimes called “orphan crops” due to the relative lack of attention they receive (Heisey et al., 2002; Pingali and Traxler, 2002; Khoury et al., 2014). The capacity of university scientists to focus on these crops has been limited by the defunding of public plant breeding programs and by shifts toward “public–private” funding models that force researchers to seek industry partners in order to receive public funds (Kuyek, 2007; Vanloqueren and Baret, 2009). In addition to the orphan crops, this approach fails to sufficiently support research areas important to farming in marginal environments and with agroecological methods; these include research on cover crops, perennial crops, and traits such as broad disease and pest resistance, improved nutrient uptake and weed competitiveness (Shelton and Tracy, 2017).

So far, we have traced the unfolding of the current seed regime and its lock-ins to the agro-industrial complex, showing how privatization and consolidation of plant breeding in the present moment rests upon deeper histories of dispossession and enclosures of seed under the first and second seed regimes. We have discussed how the first seed regime, characterized by farmer-settler seed experimentation independent of the state, gave way to the second seed regime of state intervention in agricultural innovation. We have noted how both the first and second seed regimes in the United States and Canada emerged from and in support of the expropriation of Indigenous seeds and lands and the slavery-based plantation economy. Resistance to these seed regimes has emerged repeatedly throughout this history. We now turn to examine the examples of contemporary countermovements that are actively resisting the enclosure of seed resulting from the third seed regime and its predecessors.

Seed countermovements: Community seed activists and freelance plant breeders

Two countermovements have emerged that challenge the continued enclosures of the third seed regime. One is

represented by regional *seed-saving and seed-sharing networks* that enable a horizontally distributed approach to seeds and knowledge in place of a hierarchical patent regime, demonstrating both instrumental and political motivations toward the establishment of seed commons. A second is the international *food and seed sovereignty movement* with an agenda that supports a shift in research toward collaboration between farmers and agroecological scientists. Food sovereignty is an aspiration to transform global food and agricultural systems centered on the “rights of communities to define their own food and agriculture systems” (Nyéléni Forum for Food Sovereignty, 2007, p. 88), including food cultures, markets, and access to resources (Wittman, 2011). First introduced in 1993 by La Vía Campesina, an international coalition of peasants, small-scale farmers, rural women, and Indigenous peoples, food sovereignty has entered policy debates and academic inquiry (IAASTD, 2009; IPES-Food, 2016).

Like food sovereignty, *seed sovereignty* applies a framework of human rights and self-determination by place-based communities (Bezner Kerr, 2013). The international seed sovereignty movement calls for farmer-centered and community control over seeds and seed trade; the preservation of agrobiodiversity through in situ conservation of crop genetic resources; the recognition of biocultural heritage, food security, and livelihoods in relation to seed; and the development of cultivars that thrive with low input, climate resilient agroecological methods (Borowiak, 2004; Kloppenburg, 2010a, 2010b; Tansey, 2011; ETC Group, 2013). Kloppenburg (2014) distills the seed sovereignty discourse into four attributes of seed sovereignty: (1) the right to save and replant seed, (2) the right to share seed, (3) the right to use and breed new varieties, and (4) the right to participate in shaping policies for seed. Indigenous scholars add aspects of cultural identity and spiritual meaning to discussions of seed sovereignty in North America (Hoover, 2017; White, 2018; Global Alliance for the Future of Food, 2019). Discussions of how seed systems relate to food sovereignty include calls for supporting local/informal seed markets (Sperling and McGuire, 2010) and linking formal and informal seed systems (Almekinders, 2000; Almekinders and Louwaars, 2002; Coomes et al., 2015).

Community activists, farmers, and seed savers in the United States and Canada have also formed seed networks that work toward revitalizing and adapting seeds for social and ecological needs. This is a grassroots seed mobilization primarily outside of academia, driven by farmers, seed activists, and allied nongovernmental organizations (NGOs). A pioneer in this network was the Seed Savers' Exchange, started in Iowa in 1975 by Diane Ott Whealy and Kent Whealy as a network of gardeners committed to preserving heirloom varieties (Ott Whealy, 2011). The Organic Seed Alliance, formed in 2003 in the state of Washington, has led advocacy for reinvigorated public research and development of seed for organic farming. In Canada, Seeds of Diversity grew out of a Heritage Seed Program created by Canadian Organic Growers Association in 1984; in 1995, based on the U.S. Seed Savers Exchange, it became Seeds of Diversity/Semences du patrimoine,

which sponsors “Seedy Saturday” exchanges across the country and publishes catalogues and handbooks on seed saving (Seeds of Diversity Canada, 2016). Allied organizations, such as the Bauta Family Initiative on Canadian Seed Security, have sponsored grassroots plant breeding initiatives led by farmer-researchers. These organizations have built communities of seed stewards through events, conferences, and numerous practical workshops on seed saving, sharing, exchanges, and on-farm plant breeding.

Although the global seed industry consisted of thousands of independently owned seed businesses in the 1970s, by 2015, three agrochemical firms (Monsanto, DuPont, and Syngenta) controlled 53% of the proprietary seed market (Howard, 2015). The 2016 merger of Bayer and Monsanto further reduced these to two firms, one of which controls more than 25% of the world’s seed and agrochemicals (Detrick, 2018). This concentration has numerous impacts, including placing farmers in an ever tighter financial squeeze, as seed prices rose twice as fast as farmgate commodity prices in the United States from 1990 to 2015 (IPES-Food, 2017). Responding to this unprecedented global concentration of the seed industry, seed savers and farmers working individually and as a movement have created a new ecosystem of small-scale seed companies, seed-growing collectives, and home gardeners devoted to conserving heritage and locally adapted varieties (Hubbard and Zystro, 2016). As a community, these seed stewards and entrepreneurs seek to counter the trends of the third seed regime by increasing the supply of locally adapted seeds and, as stated explicitly in the marketing logos for Adaptive Seeds in Sweet Home, Oregon, “Bringing Biodiversity Back.”

Of particular significance among these countermovements are the organizing efforts of Indigenous people, Black people, and other people of color to revitalize seeds as part of foodways, culture, and relationships to land that have been disrupted by colonialism, slavery, and systemic oppression from the first seed regime to the present. For example, networks such as the Indigenous Seed Keepers Network in the United States and Sovereignty Seeds in Canada are revitalizing traditional cultivars and seed stewardship practices as part of organizing for Indigenous food sovereignty. This includes work to “rematriate” Indigenous seeds—returning seeds of traditional varieties from public and private seed collections to the hands of the Indigenous communities that have traditionally grown and used them (Hoover, 2017; White, 2019). Meanwhile, the work of Black seedkeepers and food justice leaders such as Ira Wallace (Southern Exposure Seed Exchange), Leah Penniman (Soul Fire Farm), and Chris Bolden-Newsome (Sankofa Farm/Truelove Seeds) calls attention to seed, particularly seeds of the African diaspora, as a part of food justice and community healing (Penniman, 2018; Lawton, 2019; Neveln, 2019).

Some of these farmers and gardeners have become “freelance plant breeders,” a term promoted by plant breeder Carol Deppe to describe an emerging group of farmers and seed savers who have taken up her call to breed their own varieties adapted to organic and ecological farming, independent of university or commercial

support, by learning and sharing plant breeding techniques from their own study and through emerging relationships with allied breeders at public universities (Deppe, 2000). It is among these diverse communities of seed activists and independent farmers and gardeners, which emerged outside of the institutional lock-ins experienced by breeders in university seed programs, that we begin to see both the emergence of and challenges for community–university plant breeding partnerships framed explicitly in terms of food and seed sovereignty.

Growing over and around seed research lock-ins through community–university relationships

We have discussed how lock-ins to a reductionist paradigm in public seed research have emerged through sequential seed regimes and how community-led counter movements have resisted these enclosures of seed. We now turn to the question of how public university research programs can engage with and support movements to revitalize seed commons.

Community seed activists in North America have responded to research privatization by advocating for a renewal of public funding of variety development at public universities and for public plant breeding for organic agriculture (Tracy and Sligh, 2014; Hubbard, 2018). The Organic Seed Alliance has built relationships with public plant breeders at several land grant universities, creating long-term research collaborations between farmers, public plant breeders, and nonprofit staff to develop new varieties bred for organic agriculture (Myers et al., 2012; Shelton and Tracy, 2015; Simon et al., 2015). Simultaneously, a number of public plant breeders in both the United States and Canada have departed from a paradigm focused on extractivism and productionism to focus parts of their research programs on research and variety development of crops for diversified and agroecological farming systems (Shelton, 2014). These breeding efforts have largely focused on organic agriculture as the most organized and clearly defined community of practice advocating for plant breeding that focuses on orphan crops, varieties with higher genetic diversity (e.g., open-pollinated rather than hybrid varieties), and varieties adapted to regional conditions and agroecological practices (Navazio and Zystro, 2014). Research projects and attached funding have in turn made it possible for a new generation of graduate students to be trained in applied plant breeding methods conducive to collaboration with farmers and to breeding for organic and agroecological methods (Luby et al., 2013).

Although efforts at increasing physical access to seed (i.e., through seed exchanges) have been contained largely to the grassroots and private sector, community-led efforts to build relationships with public researchers have forged new paths for preserving legal access to seed and genetic resources. The experience of releasing a new cultivar developed through participatory research with a farmer collaborator led Shelton and Tracy (2015) to document the complex considerations that they encountered in light of university administrative protocols regarding faculty

innovations following the Bayh-Dole Act. Responding to widespread concerns about access to seed for both production and plant breeding, a coalition of faculty at the University of Wisconsin and a group of stakeholders including academics, farmers, seed companies, and seed activists developed the Open Source Seed Initiative (OSSI; Luby et al., 2015). OSSI provides a model for germplasm sharing based on the “copyleft” license of open-source software which specifies that materials can be shared but never restricted in their use (Kloppenborg, 2010a) as a form of protected commons. After much dialogue with grassroots stakeholders, the group introduced the OSSI pledge, which plant breeders (including freelance nonuniversity breeders) can use to designate new varieties as “freed seed.” Breeders and seed growers can use OSSI pledged seeds in any way they choose, with the stipulation that they may not restrict other’s use of the seeds in any way, and must include the same pledge any time the seeds are sold or exchanged (Luby et al., 2015). The majority of the 38 plant breeders who had released OSSI-pledged varieties as of 2019 are independent freelance breeders operating outside of universities. The OSSI pledge has also been taken up by the North American and Canadian seed movement and is now used by 61 independent seed companies (OSSI, 2016).

Although university rules, often governed by their technology transfer offices, prevent many public plant breeding programs from using the OSSI pledge (OSSI, 2016; Montenegro de Wit, 2017a), we argue that these initiatives toward open-source seed research make it possible to imagine other pathways for universities to contribute to revitalizing seed commons. If commons require “a resource, a community, and a set of social protocols” (Montenegro de Wit, 2017a, p. 20), then public research programs can play a positive role in facilitating, connecting, and coproducing the knowledge that communities need to maintain their resources and enact social protocols around seed. Universities can participate in such commoning by supporting freelance plant breeders and seed savers who are doing this work outside the university.

New roles for the university in supporting seed commons might include education and research in support of the skills and activities needed for broader uptake of freelance plant breeding and for community seed stewardship. This could include supporting and growing the types of knowledge networks—like those built by Organic Seed Alliance, Seed Savers’ Exchange, Seedy Saturdays, and the Indigenous Seed Keepers Network—that connect farmers and seed keepers with relevant university knowledge and resources. They could also include public plant breeders in collaborative cultivar development with farmers, including Indigenous farmers. There is also strong potential for university researchers to leverage resources in order to foster closer cross-border collaboration between grassroots communities and university scientists in the United States and Canada, in support of bioregional approaches to agricultural resilience. University researchers could explore alternative possibilities (in addition to the OSSI pledge) for handling community-directed royalties on the collaborative release of new cultivars. Such options

are already being explored by public plant breeders and community advocates (Hubbard and Zystro, 2016; Dawson et al., 2018).

More broadly, university research and outreach programs can help to support the emergence of community economies that reframe seed trade and plant breeding. The emerging diversified seed practices and relations in North America align with community (or social) economies that center “ethical negotiations around our interdependence with each other and the environment” (Gibson-Graham et al., 2013, p. 14). Public plant breeding programs can help to advance examples of plant breeding and seed systems development in this model. For example, seed growers working with some public and NGO plant breeders have begun to explore options for plant breeding cooperatives that fund future work through a cooperative royalty structure on participatory-bred varieties. Social and economic studies of alternative seed business structures are another area where public universities could contribute to the project of reframing seed production and sharing within democratic agendas for resilience. Finally, emerging examples such as the Inter-tribal Seed Stewardship Initiative, a collaboration between the University of Wisconsin plant breeders and the Ho-Chunk and Menominee Nations, show the potential of university–community relationship-building to protect and revitalize historic Indigenous varieties with a justice-oriented approach to collaborative research (NCAT-ATTRA, 2019). Such collaborations further the important project of recognizing the high productivity of Indigenous agricultural practices and how this knowledge has been devalued under colonialism (Mt. Pleasant, 2015). In addition to contributing to revitalizing seed systems beyond varietal development, these activities facilitate the development of the knowledge, relationships, and action orientation needed to move toward “systems-based breeding” which integrates multiple breeding and seed system paradigms in order to address interlinked social and environmental goals (Lammerts van Bueren et al., 2018).

The Seed Hub at the University of British Columbia

The UBC Farm Seed Hub provides a final example of how seed-related research in public universities can contribute to the project of building and maintaining seed commons. The goal of the Seed Hub is to support community seed systems in BC through interdisciplinary and community-engaged research and education. Initiated in 2012, the Seed Hub is an integrated part of the Centre for Sustainable Food Systems (CSFS), which manages UBC’s 24 hectare diversified research and education farm. The Seed Hub’s program of organic vegetable seed (re)production includes variety trials, participatory plant breeding, and seed propagation training in a diversified vegetable operation that serves as a base for educational outreach projects for UBC students, farmers, and the public. The Seed Hub also serves as a connection point for community stakeholders and CSFS-affiliated faculty to engage in plant breeding and other agroecological research that furthers knowledge for and about community-based and organic

seed systems. Although rooted at the UBC Farm, the Seed Hub engages across a broad geographic region through research and outreach to farms throughout BC, including on-farm variety trials, field days, workshops, and other knowledge sharing activities (both virtual and site-based) for farmers across Canada. The Seed Hub also fosters collaborations with local, national, and international organizations and universities to advance knowledge about plant breeding and seed systems for resilient agriculture.

The UBC Farm's current form reflects a unique history of grassroots advocacy in which students and community members led a successful campaign to protect the land and expand the UBC Farm from its earlier role as a student-led organic farm to a sustainability-related teaching and research center (Bomford, 2011). Seed production at the UBC Farm includes organic vegetable, bean, flower, and herb species integrated into broader farm production system. Each year seeds of 12–20 distinct vegetable, flower, herb, and cover crop varieties are sold on-site and on contract to two small-scale local seed companies, and through the BC EcoSeed Co-op.

Activities conducted by the Seed Hub provide examples of university engagement that can help to grow the knowledge and skills needed for creating seed commons. Seed production at the UBC Farm provides a hands-on opportunity for students and community members to learn about the techniques and tools needed to produce high-quality seed and maintain resilient varieties, including basic concepts—for example, differences between open-pollinated and hybrid varieties, self-pollinated, and cross-pollinated species—and practices such as selection and minimum population sizes to maintain genetic diversity and variety integrity. Seed production provides opportunities for students and community members to learn skills necessary for seed stewardship. Research and education conducted through the Seed Hub also builds a broader knowledge base for the development of community seed systems. For example, the Seed Hub has collaborated with local NGO FarmFolk CityFolk and several local farms to establish demonstrations of carrot seed production using pollen isolation cages to prevent cross-contamination of pollen between multiple carrot varieties or between domesticated and wild carrot (Queen Anne's Lace). The Seed Hub has also collaborated with FarmFolk CityFolk and the another nonprofit, The Bauta Family Initiative on Canadian Seed Security (BFICSS), to coordinate variety trials at the UBC Farm and 20 farms through BC from 2016 to 2018. These evaluate dozens of varieties in five crops adapted for regional seed production and with potential for future participatory plant breeding. This combination of seed production skills, knowledge about regional crop adaptation, and network building is vital to the project of creating a seed commons, which requires active and ongoing participation of a community to steward and maintain seeds as a common resource (Montenegro de Wit, 2017b).

Seed Hub activities also illustrate how universities can fulfill their commitments to community engagement through collaborative research initiatives. For example, partnership with the Seed Hub, and through it UBC, has

allowed local grassroots organizations such as FarmFolk CityFolk to leverage grant funds for shared community seed processing equipment in the form of a mobile “seed trailer” that can be moved from farm to farm. Such activities lower barriers for small seed enterprises that would otherwise lack the capital to purchase their own equipment, in turn creating possibilities for community-driven alternatives to seed industry concentration. Likewise, because of the expert personnel and seed production program of the Seed Hub, in 2012, the UBC Farm became a founding member of the BC EcoSeed Co-op. This is a producers' cooperative of small-scale diversified seed producers who collectively market seed with the mission to “increase the quantity and improve the quality of ecological and organic seed grown in BC” (BC EcoSeed Co-op, 2018). Beginning in 2018, the Seed Hub secured federal funding to extend community-driven organic vegetable variety trials and a new participatory plant breeding initiative across Canada in collaboration with the BFICSS, directing funding from the Canadian Agricultural Partnership of Agriculture Canada toward organic research. By drawing the connections and mentorship from U.S. public plant breeders and Organic Seed Alliance, Seed Hub researchers are facilitating participatory vegetable breeding project even though UBC's Faculty of Land and Food Systems lacks a formal vegetable breeding program. These developments underscore the importance of knowledge networks and civil society organizations in collaborating with universities to support diversified and agroecological seed research.

These activities sketch a reimagined role for university-based seed research and education. The pathway of the UBC Farm started with community-engaged knowledge around seed production and seed exchange, with the aim of building capacity for community seed systems including participatory and/or farmer-led plant breeding. In an era of diminished resources for public plant breeding programs and the personnel and resources they entail, community-based approaches such as that at the UBC Farm provide an alternative model. Of course, this is not a substitute for greater investment in public cultivar development, which needs to be redirected toward collaboration with farmers and place-based research, as a largely ignored United Nations-led Expert Assessment of agricultural research concluded a decade ago (IAASTD, 2009; Friedmann, 2017, pp. 1216–1217). Community-based seed research and education can help to make public research really public again and to recover dispersion of diverse, regionally adapted seeds. Collaborative science–farmer–community seed programs can build skills and knowledge that broaden the impact of public cultivar development where it does exist and strengthen freelance plant breeding in places where it does not, as a promising path toward seed system resilience.

Discussion

In a parallel to the food sovereignty movement, the discourse of seed sovereignty has been most actively adopted in Canada and the United States by Indigenous communities working to revitalize and conserve cultural

important seeds (Hoover, 2017). Emerging conversations between Indigenous seedkeepers and public researchers, for example, at events like the Food Sovereignty Symposium and Festival held in Madison, WI, in 2017, show the potential for cross-cultural work to help accomplish this recentring of experiences and knowledge (<https://food-sovereignty.com/>). At the same time, as organic farming communities have built alliances with public university programs, a sense of both enthusiasm and urgency has developed around the need for a resurgence of public plant breeding (Tracy and Sligh, 2014; Hubbard and Zystro, 2016). Advocates have been successful in maintaining a foothold in public-sector plant breeding and seed systems research. Many still question, however whether academics and community seed activists in North America can co-create a role for public research that moves beyond the inequities of both the historical “public good” and academic capitalist knowledge/learning regimes. The seed-related rights and abilities of many communities in North America have been eroded by the privatization of previously public services and the unchecked concentration of industry, resulting in reduced public cultivar development and more exclusive ownership and IP restriction of plant genetic materials. However, even before the onslaught of privatization, public agricultural research, including plant breeding, was embedded in the advance of a productivist agricultural paradigm. For lasting impact, community seed movements in North America are now more clearly articulating how their broader goals relate to seed sovereignty and the role of public research within this framework. This will be essential both to ensure ongoing institutional commitment (not just academic commitment) to community-based research and broader political momentum to advocate for increased federal funding for agroecology and other diversified agricultural approaches (DeLonge et al., 2016; Miles et al., 2017).

Community seed movements and public researchers must also question how seed systems work relates to broader issues of food sovereignty and community food justice in the context of the United States and Canada. Participatory plant breeding and seed systems research programs have been successful at identifying research areas that support farmer livelihoods through crops with stronger agronomic performance or higher market value. Yet, if renewing public seed research results narrowly in “value-added” niche cultivars, this community movement may be limited in its ability to challenge inequality in food systems. Additionally, in order to challenge the hegemonic legacy of public research, a seed sovereignty framework for the United States and Canada must engage with the colonial and racist legacies of public agricultural research. This includes seeking to center the seed knowledge of marginalized communities including, for example, migrant farmworkers, racialized farmers, and Indigenous peoples, as well as supporting community-directed seed work within these communities through concrete resources such as sharing of research funding and infrastructure. It also requires the difficult and long-term work of challenging racism and exclusion within broader university contexts in order to make plant breeding and seed

research programs more inclusive and supportive of racialized students and researchers.

Conclusion

We have explored how seed regimes in North America have evolved from resilient seed commons endemic to Indigenous communities, to enclosures by colonial land dispossession, public investment in export-oriented agricultural systems, and corporate capture of seed knowledge and distribution. A public university system originally oriented toward societal well-being also experienced a series of enclosures and lock-ins, including a narrowing of the definition of public interest to prioritize industry partnerships and commercialization opportunities, without full consideration of the social, ecological, and cultural aspects of diversified, community-based seed systems linked to traditional ecological knowledge and relationships. We then considered the example of the UBC Seed Hub to demonstrate the potential of community–university partnerships with strategic institutional commitment to expand seed literacy and engage local communities in seed networks that are building regional seed commons, including those developing and/or revitalizing locally adapted seed varieties based on the principles of the co-creation of knowledge. These networks are fostering political momentum based on a full acknowledgment that historically, land grant universities have appropriated not just land, but Indigenous knowledge and seeds. We have recognized that the potential still exists for university–community collaboration to perpetuate historical relationships of appropriation toward marginalized people, a reality that calls for continued accountability and redistribution of power and resources in collaborative research. This recognition, in turn, forms the basis of building new partnerships that advocate for universities—and federal funding agencies—to reinvest in public plant breeding while also respecting and supporting Indigenous biocultural knowledge and strengthening links between public research and grassroots seed movements. Although the strength of entrenched lock-ins within public institutions should not be underestimated, we see the potential of generative community–researcher relationships to grow over and around these lock-ins to support democratizing seed research and knowledge and bolster resilient agriculture and food sovereignty.

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References

- Almekinders, CJM.** 2000. The importance of informal seed sector and its relation with the legislative framework. *GTZ (2000 Jul. 4–5: Eschborn)*. Available at <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.195.468&rep=rep1&type=pdf>. Accessed 6 March 2021.
- Almekinders, CJM, Louwaars, NP.** 2002. The importance of the farmers' seed systems in a functional national seed sector. *Journal of New Seeds* **4**(1): 15–33. DOI: http://dx.doi.org/10.1300/J153v04n01_02.
- Ammons, S, Creamer, N, Thompson, PB, Francis, H, Friesner, J, Hoy, C, Kelly, T, Porter, C, Tomich, TP.** 2018. A deeper challenge of change: The role of land-grant universities in assessing and ending structural racism in the US food system. *Inter-Institutional Network for Food, Agriculture, and Sustainability (INFAS)* (Blog). February 22, 2018. Available at <http://asi.ucdavis.edu/networks/infas/a-deeper-challenge-of-change-the-role-of-land-grant-universities-in-assessing-and-ending-structural-racism-in-the-us-food-system>. Accessed 6 March 2021.
- BC EcoSeed Co-op.** 2018. About us. Available at <https://www.bceoseedcoop.com/pages/about-us>. Accessed 6 March 2021.
- Bezner Kerr, R.** 2013. Seed struggles and food sovereignty in Northern Malawi. *Journal of Peasant Studies* **40**(5): 867–897. DOI: <http://dx.doi.org/10.1080/03066150.2013.848428>.
- Bioversity International.** 2017. *Mainstreaming agrobiodiversity in sustainable food systems: Scientific foundations for an agrobiodiversity index*. Rome, Italy. Available at https://www.bioversityinternational.org/fileadmin/user_upload/online_library/Mainstreaming_Agrobiodiversity/Mainstreaming_Agrobiodiversity_Sustainable_Food_Systems_WEB.pdf.
- Bjørnstad, Å.** 2016. “Do not privatize the giant's shoulders”: Rethinking patents in plant breeding. *Trends in Biotechnology* **34**(8): 609–617. DOI: <http://dx.doi.org/10.1016/j.tibtech.2016.02.007>.
- Boett, AB.** 2006. Bayh-Dole: If we knew then what we know now. *Nature Biotechnology* **24**(3): 320–323. DOI: <http://dx.doi.org/10.1038/nbt0306-320>.
- Bomford, M.** 2011. University of British Columbia: The improbable farm in the World City, in Sayre, L. ed., *Fields of learning: the Student Farm Movement in North America*. University of Kentucky Press, Lexington: 249–268.
- Borowiak, C.** 2004. Farmers' rights: Intellectual property regimes and the struggle over seeds. *Politics & Society* **32**(4): 511–543. DOI: <http://dx.doi.org/10.1177/0032329204269979>.
- Boyd, M, Surette, C.** 2010. Northernmost Precontact Maize in North America. *American Antiquity* **75**(1): 117–133.
- Buttel, FH, Busch, L.** 1988. The public agricultural research system at the crossroads. *Agricultural History* **62**(2): 303–324.
- Carney, JA.** 2013. Seeds of memory: Botanical legacies of the African Diaspora, in Voeks, R, Rashford, J eds., *African Ethnobotany in the Americas*. New York: Springer-Verlag. DOI: <http://dx.doi.org/10.1007/978-1-4614-0836-9>.
- Carter, TE, Tracy, WF, Sinclair, TR, Isleib, TG, Joos, R.** 2014. What is the state of public cultivar development?, in Tracy, WF, Sligh, M eds., *Proceedings of the 2014 Summit on Seeds and Breeds for 21st Century Agriculture*. Washington, DC: Rural Advancement Foundation International-USA: 42–73.
- Clapp, J.** 2019. The rise of financial investment and common ownership in global agrifood firms. *Review of International Political Economy*. 1–26. DOI: <http://dx.doi.org/10.1080/09692290.2019.1597755>.
- Coomes, OT, McGuire, SJ, Garine, E, Caillon, S, McKey, D, Demeulenaere, E, Jarvis, D, Aistara, G, Barnaud, A, Clouvel, P, Emperaire, L, Louafi, S, Martin, P, Massol, F, Pautasso, M, Violon, C, Wencélius, J.** 2015. Farmer seed networks make a limited contribution to agriculture? Four common misconceptions. *Food Policy* **56**(October): 41–50. DOI: <http://dx.doi.org/10.1016/j.foodpol.2015.07.008>.
- Cronon, W.** 1992. *Nature's Metropolis: Chicago and the Great West*. Reprint edition. New York, NY: W. W. Norton.
- Dawson, JC, Moore, VM, Tracy, WF.** 2018. Establishing best practices for germplasm exchange, intellectual property rights, and revenue return to sustain public cultivar development. *Crop Science* **58**(2): 469. DOI: <http://dx.doi.org/10.2135/cropsci2017.05.0320>.
- DeLonge, MS, Miles, A, Carlisle, L.** 2016. Investing in the transition to sustainable agriculture. *Environmental Science & Policy* **55**(January): 266–73. DOI: <http://dx.doi.org/10.1016/j.envsci.2015.09.013>.
- DePauw, RM, Boughton, GR, Knott, DR.** 1995. Hard red spring wheat, in Knott, DR, Slinkard, AE eds., *Harvest of gold: The history of field crop breeding in Canada*. Saskatoon, Canada: University Extension Press, University of Saskatchewan.
- Deppe, C.** 2000. *Breed your own vegetable varieties: The gardener's and farmer's guide to plant breeding and seed saving*. White River Junction, VT: Chelsea Green Publishing.

- Detrick, H.** 2018. The justice department is going to let Bayer buy Monsanto. Here's why it matters. *Fortune*, April 10, 2018. Available at <http://fortune.com/2018/04/10/bayer-monsanto-deal-doj-approval/>. Accessed 6 March 2021.
- ETC Group.** 2013. **Putting the Cartel before the Horse . . . and Farm, Seeds, Soil, Peasants, Etc. Comunique no. 111.** Available at http://www.etcgroup.org/putting_the_cartel_before_the_horse_2013. Accessed 6 March 2021.
- Fanzo, J, Hunter, D, Borelli, T, Mattei, F eds.** 2013. *Diversifying food and diets: Using agricultural biodiversity to improve nutrition and health.* First edition. New York, NY: Routledge (Issues in Agricultural Biodiversity).
- Frey, KJ.** 1996. National plant breeding study-I: Human and financial resources devoted to plant breeding research and development in the United States in 1994. Spec. Rep. 98. Ames: Iowa Agric. and Home Economics Exp. Stn. Available at <https://nifa.usda.gov/sites/default/files/resource/National%20Plant%20Breeding%20Study-1.pdf>. Accessed 6 March 2021.
- Friedmann, H.** 2000. What on earth is the modern world-system? Foodgetting and territory in the modern era and beyond. *Journal of World-Systems Research* **6**(2): 480–515. DOI: <http://dx.doi.org/10.5195/jwsr.2000.214>.
- Friedmann, H.** 2017. Paradox of transition: Two reports on how to move towards sustainable food systems: Assessment: Sustainable food systems and the paradox of transition. *Development and Change* **48**(5): 1210–1226. DOI: <http://dx.doi.org/10.1111/dech.12329>.
- Friedmann, H, McMichael, P.** 1989. Agriculture and the state system—The rise and decline of national agricultures, 1870 to the present. *Sociologia Ruralis* **29**: 93–117.
- Gibson-Graham, JK, Cameron, J, Healy, S.** 2013. *Take back the economy: An ethical guide for transforming our communities.* Minneapolis, MN: University of Minnesota Press.
- Gill, DS.** 1996. *Reframing agricultural extension education services in industrially developed countries: A Canadian perspective.* Education and Research Archive. 1996. DOI: <http://dx.doi.org/10.7939/R3GQ6R292>.
- Global Alliance for the Future of Food.** 2019. *Beacons of hope: Transforming food systems.* Beacons of Hope. February 26, 2019. Available at <https://foodsystemtransformations.org/>. Accessed 6 March 2021.
- Goldstein, JE, Paprocki, K, Osborne, T.** 2019. A manifesto for a progressive land-grant mission in an Authoritarian Populist Era. *Annals of the American Association of Geographers* **109**(2): 673–84. DOI: <http://dx.doi.org/10.1080/24694452.2018.1539648>.
- Griesbach, RJ.** 2013. *150 Years of research at the United States Department of Agriculture: Plant introduction and breeding.* Washington, DC: U.S. Department of Agriculture, Agricultural Research Service.
- Gwin, P.** 2019. What if the seeds do not sprout? The Cherokee Nation SeedBank & Native Plant Site, in Mihe-suah, DA, Hoover, E, LaDuke, W. eds., *Indigenous food sovereignty in the United States: Restoring cultural knowledge, protecting environments, and regaining health.* Norman, OK: University of Oklahoma Press.
- Harwood, J.** 2019. Could the adverse consequences of the green revolution have been foreseen? How experts responded to unwelcome evidence. *Agroecology and Sustainable Food Systems* 1–27. DOI: <http://dx.doi.org/10.1080/21683565.2019.1644411>.
- Hecquet, C, Hermesse, J, Stassart, PM.** 2018. The “lock-in” of the seed system and issues arising from its reappropriation. *Études Rurales* **2**:10.
- Heisey, PW, Srinivasan, CS, Thirtle, C.** 2001. **Public sector plant breeding in a privatizing world. Agriculture Information Bulletin No. 772.** Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Available at https://web.archive.org/web/20120206230202if_/http://www.ers.usda.gov/publications/aib772/aib772.pdf. Accessed 6 March 2021.
- Heisey, PW, Srinivasan, CS, Thirtle, C.** 2002. Privatization of plant breeding in industrialized countries: Causes, consequences and the public sector response, in Byerlee, D, Echeverría, RG eds., *Agricultural research policy in an era of privatization.* Wallingford, UK: CABI Publishing: 177–198.
- Hoover, E.** 2017. “You can't say you're sovereign if you can't feed yourself”: Defining and enacting food sovereignty in American Indian Community Gardening. *American Indian Culture and Research Journal* **41**(3): 31–70. DOI: <http://dx.doi.org/10.17953/aicrj.41.3.hoover>.
- Howard, PH.** 2015. Intellectual property and consolidation in the seed industry. *Crop Science* **55**(6): 2489. DOI: <http://dx.doi.org/10.2135/cropsci2014.09.0669>.
- Hubbard, K.** 2018. *Seeds for the future act will support public plant breeding.* Organic Seed Alliance. March 9, 2018. Available at <https://seedalliance.org/2018/seeds-future-act-will-increase-support-public-plant-breeding/>. Accessed 6 March 2021.
- Hubbard, K, Zystro, J.** 2016. *State of organic seed, 2016.* Port Townsend, WA: Organic Seed Alliance. Available at <http://stateoforganicseed.org/wp-content/uploads/2017/01/SOS-2016-report-FINAL-DIGITAL.pdf>. Accessed 6 March 2021.
- IAASTD.** 2009. *Agriculture at a crossroads: International assessment of agricultural knowledge, science and technology for development, synthesis report.* Washington, DC: International Assessment of Agricultural Knowledge, Science and Technology for Development.
- IPES-Food.** 2016. *From uniformity to diversity: A paradigm shift from industrial agriculture to diversified agroecological systems.* Available at <http://www.ipes-food>.

org/_img/upload/files/UniformityToDiversity_FULL.pdf. Accessed 6 March 2021.

- IPES-Food.** 2017. *Too big to feed: Exploring the impacts of mega-mergers, consolidation, and concentration of power in the agri-food sector.* Available at http://www.ipes-food.org/_img/upload/files/Concentration_FullReport.pdf. Accessed 6 March 2021.
- Jaruzelski, B, Staack, V, Johnson, T.** 2017. The role of private-sector R&D in agricultural innovation: Improving yields, equipment productivity, and sustainability, in Cornell University, INSEAD, and WIPO eds., *The Global Innovation Index 2017: Innovation Feeding the World, Ithaca, Fontainebleau, and Geneva.* 89–95.
- Jones, SM.** 2013. Agricultural research stations, in *The Canadian encyclopedia.* Available at <http://www.thecanadianencyclopedia.ca/en/article/agricultural-research-stations/>. Accessed 6 March 2021.
- Keeve, CB.** 2020. *Fugitive seeds.* Edge Effects. February 25, 2020. Available at <https://edgeeffects.net/fugitive-seeds/>. Accessed 6 March 2021.
- Khoury, CK, Bjorkman, AD, Dempewolf, H, Ramirez-Villegas, J, Guarino, L, Jarvis, A, Rieseberg, LH, Struik, PC.** 2014. Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences* **111**(11): 4001–4006. DOI: <http://dx.doi.org/10.1073/pnas.1313490111>.
- Klein, KK.** 2001. Publicly funded research in agriculture: Time for a shift in paradigm? *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroéconomie* **49**(4): 395–413. DOI: <http://dx.doi.org/10.1111/j.1744-7976.2001.tb00315.x>.
- Kloppenburg, J.** 2004. *First the seed: The political economy of plant biotechnology, 1492–2000.* Second edition. Madison, WI: University of Wisconsin Press (Science and Technology in Society).
- Kloppenburg, J.** 2010a. Impeding dispossession, enabling repossession: Biological open source and the recovery of seed sovereignty. *Journal of Agrarian Change* **10**(3): 367–388.
- Kloppenburg, J.** 2010b. Seed sovereignty: The promise of open source biology, in Wittman, H, Desmarais, AA, Wiebe, N eds., *Food sovereignty: Reconnecting food, nature & community.* Halifax, Canada: Fernwood Publishing.
- Kloppenburg, J.** 2014. Re-purposing the master's tools: The open source seed initiative and the struggle for seed sovereignty. *The Journal of Peasant Studies* **41**(6): 1225–1246. DOI: <http://dx.doi.org/10.1080/03066150.2013.875897>.
- Knight, J.** February 6, 2003. Crop improvement: A dying breed. *Nature.* 2003. DOI: <http://dx.doi.org/10.1038/421568a>.
- Kotschi, J, von Lossau, A.** 2011. *Agrobiodiversity—The key to food security and adaptation to climate change.* Bonn, Germany: Federal Ministry for Economic Cooperation and Development, Programme on Sustainable Management of Resources in Agriculture. Available at <https://kotschi.eu/wp-content/uploads/2014/02/KotschiLossau-engl-2011.pdf>. Accessed 6 March 2021.
- Kumar, R.** 2016. *Rethinking revolutions: Soyabean, choupals, and the changing countryside in Central India.* Oxford University Press.
- Kuyek, D.** 2007. Sowing the seeds of corporate agriculture: The rise of Canada's third seed regime. *Studies in Political Economy* **80**(1): 31–54. DOI: <http://dx.doi.org/10.1080/19187033.2007.11675082>.
- Lammerts van Bueren, ET, Struik, PC, van Eekeren, N, Nuijten, E.** 2018. Towards resilience through systems-based plant breeding. A review. *Agronomy for Sustainable Development* **38**(5): 42. DOI: <http://dx.doi.org/10.1007/s13593-018-0522-6>.
- Lawton, C.** 2019. Celebrating pride: The stories of the past are told in the seeds of today. *WhyHunger* (Blog). June 2019. Available at <https://whyhunger.org/category/blog/celebrating-pride-the-stories-of-the-past-are-told-in-the-seeds-of-today/>. Accessed 6 March 2021.
- Lee, R, Ahtone, T, Pearce, M, Goodluck, K, McGhee, G, Leff, C, Lanpher, K, Salinas, T.** 2020. *Land grab universities: A high country news investigation.* Land Grab Universities. Available at <https://www.landgrabu.org>. Accessed 6 March 2021.
- Lianos, I, Katalevsky, D.** October 2017. Merger activity in the factors of production segments of the food value chain: A critical assessment of the Bayer/Monsanto merger. Working/discussion paper (CLES Policy Papers 01/2017). London, UK: Centre for Law, Economics and Society, UCL Faculty of Laws. Available at <https://discovery.ucl.ac.uk/id/eprint/10045082/>. Accessed 6 March 2021.
- Lipton, M, Longhurst, R.** 1989. *New seeds and poor people.* Baltimore, MD: Johns Hopkins University Press (The Johns Hopkins Studies in Development).
- Lowe, P, Murdoch, J, Marsden, T, Munton, R, Flynn, A.** 1993. Regulating the new rural spaces: The uneven development of land. *Journal of Rural Studies* **9**(3): 205–222. DOI: [http://dx.doi.org/10.1016/0743-0167\(93\)90067-T](http://dx.doi.org/10.1016/0743-0167(93)90067-T).
- Luby, CH, Kloppenburg, J, Michaels, TE, Goldman, IL.** 2015. Enhancing freedom to operate for plant breeders and farmers through open source plant breeding. *Crop Science.* DOI: <http://dx.doi.org/10.2135/cropsci2014.10.0708>.
- Luby, CH, Lyon, AH, Shelton, A.** 2013. A new generation of plant breeders discovers fertile ground in organic agriculture. *Sustainability* **5**(6): 2722–2726. DOI: <http://dx.doi.org/10.3390/su5062722>.
- Mcdowell, GR.** 2003. Engaged universities: Lessons from the land-grant universities and extension. *The ANNALS of the American Academy of Political and Social Science* **585**(1): 31–50. DOI: <http://dx.doi.org/10.1177/0002716202238565>.
- Metcalfe, AS.** 2010. Revisiting academic capitalism in Canada: No longer the exception. *The Journal of Higher Education* **81**(4): 489–514.

- Miles, A, DeLonge, MS, Carlisle, L.** 2017. Triggering a positive research and policy feedback cycle to support a transition to agroecology and sustainable food systems. *Agroecology and Sustainable Food Systems* **41**(7): 855–79. DOI: <http://dx.doi.org/10.1080/21683565.2017.1331179>.
- Montenegro de Wit, M.** 2017a. Beating the bounds: How does “open source” become a seed commons? *The Journal of Peasant Studies*. 1–36. DOI: <http://dx.doi.org/10.1080/03066150.2017.1383395>.
- Montenegro de Wit, M.** 2017b. Stealing into the wild: Conservation science, plant breeding and the makings of new seed enclosures. *The Journal of Peasant Studies* **44**(1): 169–212. DOI: <http://dx.doi.org/10.1080/03066150.2016.1168405>.
- Mt. Pleasant, J.** 2015. A new paradigm for pre-Columbian agriculture in North America. *Early American Studies: An Interdisciplinary Journal* **13**(2): 374–412.
- Mueller, NG.** 2018. The earliest occurrence of a newly described domesticate in Eastern North America: Adena/Hopewell communities and agricultural innovation. *Journal of Anthropological Archaeology* **49**(March): 39–50. DOI: <http://dx.doi.org/10.1016/j.jaa.2017.12.001>.
- Myers, J, McKenzie, L, Mazourek, M, Tracy, WF, Shelton, A, Navazio, J.** 2012. Breeding peas, sweet corn, broccoli, winter squash, and carrots as part of the northern organic vegetable improvement collaborative (NOVIC), in *Strengthening Community Seed Systems. Proceedings of the 6th Organic Seed Growers Conference, Port Townsend, Washington, USA, 19–21 January, 2012*, 44–45. Organic Seed Alliance. Available at <http://isplb03-aux3.semantics.net/abstracts/20123176030.html;jsessid=0696515124033408B8B91A075AF95D70>. Accessed 13 October 2016.
- Nabhan, GP.** 1989. *Enduring seeds: Native American agriculture and wild plant conservation*. Tuscon, AZ: University of Arizona Press.
- Navazio, J, Zystro, J.** 2014. *Introduction to on-farm organic plant breeding*. Port Townsend, WA: Organic Seed Alliance.
- National Center for Appropriate Technology–Appropriate Technology Transfer for Rural Areas (NCAT-ATTRA).** 2019. Intertribal seed stewardship initiative launched. *ATTRA Sustainable Agriculture* (Blog). February 27, 2019. Available at <https://attra.ncat.org/intertribal-seed-stewardship-initiative-launched/>. Accessed 6 March 2021.
- Neveln, V.** 2019. Ira Wallace: Seed saver extraordinaire. *The American Gardener*, June, 38–39.
- Nyéleni Forum for Food Sovereignty.** 2007. *Declaration of the forum for food sovereignty*. Selingué, Mali: Nyéleni Forum for Food Sovereignty.
- Open Source Seed Initiative.** 2016. *Seed company partners*. Open Source Seed Initiative. Available at <https://osseeds.org/seed-company-partners/>. Accessed 6 March 2021.
- Open Source Seed Initiative.** 2016. *Plant breeders*. Open Source Seed Initiative. Available at <https://osseeds.org/people/>. Accessed 6 March 2021.
- Ostrom, E.** 1990. *Governing the commons: The evolution of institutions for collective action*. Cambridge, UK: Cambridge University Press.
- Ott Whealy, D.** 2011. *Gathering: Memoir of a seed saver*. Decorah, IA: Seed Savers Exchange.
- Penniman, L.** 2018. *Farming while black: Soul fire farm's practical guide to liberation on the land*. White River Junction, VT: Chelsea Green Publishing.
- Pingali, PL, Traxler, G.** 2002. Changing locus of agricultural research: Will the poor benefit from biotechnology and privatization trends? *Food Policy* **27**(3): 223–238. DOI: [http://dx.doi.org/10.1016/S0306-9192\(02\)00012-X](http://dx.doi.org/10.1016/S0306-9192(02)00012-X).
- Pray, CE, Fuglie, KO.** 2015. Agricultural research by the private sector. *Annual Review of Resource Economics* **7**(1): 399–424. DOI: <http://dx.doi.org/10.1146/annurev-resource-100814-125115>.
- Seeds of Diversity Canada.** 2016. *Seedy Saturdays and events*. Available at <https://seeds.ca/events>. Accessed 6 March 2021.
- Shelton, A.** 2014. *Plant breeding for organic agriculture in the United States: A new paradigm*. Madison, WI: University of Wisconsin–Madison.
- Shelton, A, Tracy, WF.** 2015. Recurrent selection and participatory plant breeding for improvement of two organic open-pollinated sweet corn (*Zea Mays* L.) populations. *Sustainability* **7**(5): 5139–5152. DOI: <http://dx.doi.org/10.3390/su7055139>.
- Shelton, A, Tracy, WF.** 2017. Cultivar development in the U.S. public sector. *Crop Science* **57**(4): 1823. DOI: <http://dx.doi.org/10.2135/cropsci2016.11.0961>.
- Simon, P, Colley, M, Colquhoun, J, duToit, L, Hoagland, L, McKenzie, L, Nunez, J, Roberst, P, Silva, E, Waters, T, Zystro, J, McCluskey, C.** 2015. *Carrot improvement for organic agriculture with added grower and consumer value* (Poster). Available at https://eorganic.info/sites/eorganic.info/files/Poster_CIOA_January2017_FINAL.pdf.
- Slaughter, S, Leslie, LL.** 1997. *Academic capitalism: Politics, policies, and the entrepreneurial university*. Baltimore, MD: Johns Hopkins University Press.
- Slaughter, S, Rhoades, G.** 2004. *Academic capitalism and the new economy: Markets, state, and higher education*. Baltimore, MD: Johns Hopkins University Press.
- Sperling, L, McGuire, SJ.** 2010. Understanding and strengthening informal seed markets. *Experimental Agriculture* **46**(2): 119. DOI: <http://dx.doi.org/10.1017/S0014479709991074>.
- Tansey, G.** 2011. Whose power to control? Some reflections on seed systems and food security in a changing world. *IDS Bulletin* **42**(4): 111–120. DOI: <http://dx.doi.org/10.1111/j.1759-5436.2011.00241.x>.
- Tracy, WF, Sligh, M eds.** 2014. *Proceedings of the 2014 summit on seeds and breeds for 21st century agriculture*. Washington, DC: Rural Advancement Foundation International (RAFI). Available at <http://rafusa.org/docs/2014SummitProceedings.pdf>.

- Twitty, MW.** 2017. *The cooking gene: A journey through African American culinary history in the old south*. Reprint edition. New York, NY: Amistad.
- Vanloqueren, G, Baret, PV.** 2009. How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. *Research Policy* **38**(6): 971–983. DOI: <http://dx.doi.org/10.1016/j.respol.2009.02.008>.
- White, R.** 2018. Seed Rematriation. *Sierra Seeds* (Blog). March 19, 2018. Available at <http://sierraseeds.org/seed-rematriation/>. Accessed 6 March 2021.
- White, R.** 2019. Planting sacred seeds in a modern world: Restoring indigenous seed sovereignty, in Mihesuah, DA, Hoover, E, LaDuke, W. eds., *Indigenous food sovereignty in the United States: Restoring cultural knowledge, protecting environments, and regaining health*. Norman, OK: University of Oklahoma Press. Available at <http://ebookcentral.proquest.com/lib/ubc/detail.action?docID=5838903>.
- White, WJ.** 1995. Plant breeding in Canada's formative years, in *Harvest of gold: The history of field crop breeding in Canada*. Saskatoon, Canada: University Extension Press, University of Saskatchewan.
- Wittman, H.** 2011. Food sovereignty: A new rights framework for food and nature? *Environment and Society: Advances in Research* **2**(1): 87–105. DOI: <http://dx.doi.org/10.3167/ares.2011.020106>.
- Zerbe, N.** 2015. Plant genetic resources in an age of global capitalism. *Canadian Food Studies/La Revue canadienne des études sur l'alimentation* **22**: 194–200. DOI: <http://dx.doi.org/10.15353/cfs-rcea.v2i2.117>.

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