6 Labor and the Problem of Herbicide Resistance: How Immigration Policies in the United States and Canada Impact Technological Development in Grain Crops

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Introduction

In order to maintain its system of productivist industrialized agriculture, the United States relies heavily on migrant farm laborers (Bonanno 2015; Guan et al. 2015; Zahniser et al. 2018). With domestic workers unwilling to take such low-status, physically demanding, and low-paying jobs (Bonanno 2015; Zahniser et al. 2018), it has become necessary to depend on migrants. The United States gets the majority of its migrant farm labor from Mexico, with most of these workers coming seasonally to harvest horticultural and other specialty crops (Martin 2009; Zahniser et al. 2018). The reliance on these workers, however, has significant risks attached to it. With current political and social trends in the United States, migrant labor shortages have become a serious problem (Fan et al. 2015; Zahniser et al. 2018). This has the potential to devastate sectors of US agriculture that cannot function without the readily available and low-cost hand labor that Mexican migrant farm laborers provide.

The impact of foreign workers' availability on horticulture—and in particular its correlation with mechanization—has been well documented (e.g., Bellenger et al. 2008; Fan et al. 2015; Martin 2013). However, the effect on commodity field crops has been deemed largely irrelevant because of already high levels of mechanization in these systems (Martin 2013). Indeed, in the United States, only about 13% of migrant farmworkers are employed in field and grain cropping systems, whereas 84% work in fruit, vegetable, or nut farming systems (Hernandez, Gabbard, and Carroll 2016). This leads to the assumption that labor shortages will have minimal impact on the viability of US commodity grain crops (e.g., Zahniser et al. 2018). However,

the problem of herbicide-resistant (HR) weeds is challenging this assumption. Many weed species have become resistant to popular herbicides, and no new herbicidal mode of action appears to be forthcoming (Livingston et al. 2015). Thus, controlling herbicide resistance in commodity grain crops increasingly requires removing weeds through manual labor—a role traditionally filled by Mexican immigrants.

Herbicide-resistant weeds are the result of reliance on an herbicide-only weed management system, and they present a significant threat to the profitability and continuity of commodity grain crop farms in the United States. Such weeds can devastate crop yields and cause the cost of production to skyrocket—in particular, the cost of hiring hand labor to remove resistant weeds from the field (Norsworthy et al. 2012). An alternative to herbicide-only weed management, integrated weed management (IWM), involves the integration of preventative, mechanical, cultural, chemical, and biological weed management techniques. This combination provides effective weed management while also avoiding development of herbicide resistance (Harker 2013). However, such programs often rely on the availability of hand labor, necessitating the use of foreign migrant laborers (Harker 2013). Therefore, the trend in availability of such laborers will likely have a meaningful impact on how commodity grain crop growers control their weeds.

Using focus group data with farmers from Minnesota, Iowa, Arkansas, and North Carolina, we address the issue of US foreign farm laborer dynamics in relation to herbicide resistance and commodity grain crops. Within our focus groups, labor shortages emerged as a relevant barrier to HR weed control, leading to significant challenges and concerns. Drawing from theory developed in a study of labor relations in the lettuce industry in California (Friedland et al. 1981), we investigate how this decrease in immigrant labor, specifically from Mexico, is impacting reliance on technological innovation in the herbicide industry and creating a counterpart to labor struggles and mechanization trends in horticulture.

Additionally, we assess two potential futures for HR weed management as a function of how national policies, programs, and social attitudes are impacting labor availability. We accomplish this via a comparison between our firsthand data from the United States and theoretical analysis of Canada's policies for temporary agricultural workers. Similar herbicide-resistance problems (see Heap 2017) and comparable reliance on Mexican temporary farmworkers (see Bonanno 2015; Weiler, McLaughlin, and Cole 2017a) in

the United States and Canada provide a controlled context in which to test the impact of these political and cultural differences on future HR weed management outcomes, highlighting the importance of national immigration policies in determining systems of management in agriculture. This follows important work by Brandt (2002) documenting the work of Mexican women farmworkers along the tomato processing route between Mexico, the United States, and Canada. Our analysis integrates the social science area of immigrant labor issues and the physical science area of crop management—two areas that are not typically conceptualized as connected yet are becoming increasingly so in the lived experiences of farmers and laborers. Through this approach, this research will lend itself to new ways of discussing crop science and social issues as conjointly constituted, emphasizing the necessity for an interdisciplinary perspective in fields from food system studies, to agricultural science, to immigration politics.

Theoretical Background

When discussing labor shortages, the most common recommendation in horticulture is to mechanize (e.g., Guan et al. 2015; Halle 2007; Taylor, Charlton, and Yúnez-Naude 2012; Zahniser et al. 2018). Even when mechanization is not necessarily recommended, it is the common outcome of decreasing farmworker availability (Martin 2013). This trend reflects Friedland and colleagues' (1981) study of manufacturing in the lettuce and tomato industries. In their research, they posited that the elasticity and control of the labor supply plus the economic structure of an industry determines the type and extent of technological change in production.

The context for Friedland and colleagues' study was California in the 1960s, just before the end of the Bracero Program, which had been providing a reliable source of inexpensive (i.e., underpaid), legal immigrant labor. To deal with the anticipated labor shortage, the tomato industry threw substantial funding behind the development of mechanical harvesting technology. In contrast, the lettuce industry was less coordinated and slower to develop mechanization to replace migrant labor. Soon it became apparent that supplies of underpaid immigrant labor would continue unabated, largely because of undocumented immigrants, and that mechanization was no longer necessary. The lettuce industry ceased its research into mechanics, and throughout the 1970s, mechanization in the lettuce industry was

limited by the efficiency of labor-intensive harvesting processes and the continued availability of underpaid labor. Friedland and colleagues (1981) proceeded to hypothesize three conditions that could theoretically induce mechanization in the lettuce industry: (1) blockage of the labor supply through limited migration and increased union organization, (2) reduction in the production cost of mechanical solutions, and (3) relocation of the lettuce industry from California to Florida, which would limit the number of Mexican migrants available to do harvesting. These conditions would essentially reproduce the context that led to significant mechanization in the tomato industry: a prolonged labor shortage combined with the relatively rapid development of cost-efficient mechanical laborsaving technologies.

In order to predict whether commodity grain growers in the United States and Canada will turn to mechanization for HR weed control, Friedland and colleagues (1981) suggest that we must first understand the two countries' migrant labor policies. Therefore, if there were significant differences between temporary migrant farmworker policies in the United States and Canada, we would likely see differences in how they propose to manage HR weeds. We discuss the literature on migrant farmworker programs in the United States and Canada to explore their respective effectiveness and problems.

Agricultural Labor Shortages and Farmworker Programs in the United States

The systems of US immigration and agricultural labor have long been interconnected (Devadoss and Luckstead 2011). Approximately 68% of all hired farm laborers in the United States are Mexican citizens, and 47% of all farmworkers are not legally authorized to work in the United States, according to self-reports from a 2013–2014 survey (Hernandez, Gabbard, and Carroll 2016). Since this is a self-reported statistic, the reality is that the percentage is likely much higher. Indeed, the organization Farmworker Justice puts the estimate of unauthorized migrant farmworkers at over 70% (Boudreau 2016), and the American Farm Bureau estimates between 50% and 70% (Zahniser et al. 2018). As unauthorized laborers, this population is particularly vulnerable to the industry's control and abuse.

Media and political rhetoric in the United States have historically held a negative attitude toward undocumented immigration (Martin 2015),

and national immigration policies increasingly reflect this. Tougher border enforcement, the expansion of the US-Mexico border fence, and crossing conditions that are more dangerous and costly have drastically decreased the number of agricultural workers making the trip north since the late 1990s (Devadoss and Luckstead 2011; Fan et al. 2015; Martin 2013). Additionally, increased spending on domestic enforcement against undocumented workers—for instance, in the form of I-9 audits[1] and state-mandated E-Verify[2] programs to check workers' legal status—has been shown to have decreased undocumented farm labor employment and caused locally based labor shortages in the agricultural sector since 2006 (Devadoss and Luckstead 2011; Martin 2013). A 2018 report by the US Department of Agriculture concurs that the number of unauthorized Mexican immigrants has declined substantially, contributing to the tightening of the farm labor market in the United States (Zahniser et al. 2018). The Trump administration has aggravated this issue, as the president made migration a central issue in his 2016 campaign. Since taking office, he has enacted plans to build a wall on the Mexico-US border, increase the number of Border Patrol and Immigration and Customs Enforcement agents, and reduce the admission of foreigners more generally, resulting in a substantial decline in illegal migration between Mexico and the United States (Martin 2019).

In an attempt to better control the hiring of foreign farmworkers, the Immigration Reform and Control Act introduced section H-2A in 1986. Although a multitude of reforms to this program have been proposed since then—including the H-2C program championed by former Virginia representative Bob Goodlatte in 2018—none have passed (Martin 2019). This makes H-2A farmers' current best option for hiring foreign workers legally (Rickard 2015). H-2A hiring of foreign workers is allowable only if there are not sufficient domestic workers available and if hiring foreign workers will not negatively affect local wages (Bellenger et al. 2008). Producers must submit a request for workers to the Department of Labor (DOL) 60 days before they think they will need them. Once the DOL verifies that there is a need for immigrant farmworkers in the area, the request is transferred to US Citizenship and Naturalization Services, which recruits the appropriate workers. Although this process is supposed to take only 60 days, some farmers have complained of delays of up to an additional five weeks (Boudreau 2016). This program's intention is to alleviate the labor shortage; however, it is time consuming and difficult to use, discouraging both producers and

migrants from employing it (Devadoss and Luckstead 2011). These conditions likely encourage the use of undocumented laborers, as employers see little advantage to hiring through H-2A versus hiring undocumented laborers, and anticipate clear advantages to their bottom line by using this less-protected undocumented labor population (Danger 2000).

In addition to the bureaucratic problems H-2A presents for employers, some legal experts compare worker conditions under H-2A to slavery or indentured servitude (e.g., Guerra 2004; Hall 2001). Indeed, conditions are often deplorable and workers' rights nearly nonexistent. Immigrant laborers hired under H-2A can only work for the grower that recruited them, locking them into a potentially poor work environment and leaving them susceptible to exploitation by employers who have the power to refer them to the authorities for deportation or blacklist them from future H-2A employment (Danger 2000; Guerra 2004; Hall 2001; Simms 2000). Additionally, workers do not see their contracts until they arrive in the United States, cannot choose their employer, cannot negotiate their wages, are excluded from the Migrant and Seasonal Agricultural Worker Protection Act, cannot sue their employer, and often face substandard housing conditions and very low wages (Danger 2000; Guerra 2004; Hall 2001; Simms 2000). Furthermore, H-2A reforms that benefit workers do not appear to be forthcoming, not in the least because of farmers' opposition to such reforms, as the current system clearly favors the employers over the employees (Norton 2016). Lobbying efforts to reform H-2A have focused on making it easier for farmers to bring in temporary workers, specifically lobbying for the removal of preferences for US laborers, for the reduction of temporary farmworker wages, and against the general sluggishness of the program (Tomson 2015; Francis 2018; Wheat 2018).

Despite these issues, farmers' H-2A requests are growing as border enforcement increases and immigration reform seems far off (Martin 2019). Specifically, H-2A requests are rising in response to the increasing labor shortage and the Trump administration's tougher enforcement of immigration laws, which is expected to decrease the availability of undocumented migrant agricultural workers (see chapter 1 of this volume for Kimberley Curtis's analysis of migrant farmworkers and increased border militarization in Arizona). In the first three months of 2017, 69,272 H-2A positions had been requested, a 36% increase from the same period in 2016 and by far the biggest jump in recent years (Charles 2017). Roughly 200,000 H-2A positions

were certified in 2017 (91% of which went to Mexicans), and the first three quarters of 2018 suggest that certifications will jump another 21% (Zahniser et al. 2018). Ironically, President Trump himself employs H-2A farm guest workers at his Virginia vineyard (Martin 2019). Despite this increasing use of H-2A, which may be indicative of the labor shortage farmers are experiencing (Zahniser et al. 2018), experts anticipate that unless the program is reformed, labor shortages will continue to rise, with concomitant drops in agricultural productivity and value (e.g., O'Brien, Kruse, and Kruse 2014; Simms 2000; Zahniser et al. 2018). In the current US political climate, such enforcements, barriers, and stagnant policies are likely to continue to magnify unprecedented labor shortages (Guan et al. 2015; Martin 2019; Taylor et al. 2012). In particular, labor shortages will have a newly significant impact on farm industries traditionally thought of as not being highly labor dependent. This is likely to increase competition with the horticulture industry for laborers, further complicating migrant labor shortages. The assumption by most scholars that labor is not an issue on commodity grain farms is faulty and needs to be challenged in order to effectively address these issues.

Agricultural Labor Shortages and Farmworker Programs in Canada

The struggles with domestic labor availability that Canada faces are similar to those facing the United States (Preibisch 2010). However, in contrast to the US H-2A program, Canada's Seasonal Agricultural Worker Program (SAWP) is consistently cited as a model temporary agricultural worker program for its circularity—meaning workers who come to Canada rarely overstay their visas, instead returning to their home country and getting a new visa to return to Canada the following year (e.g., Castles, de Haas, and Miller 2014; Hennebry and Preibisch 2012; Massey and Brown 2011). Developed in 1966, the program allows agricultural employers in specific commodity sectors to recruit and hire workers who are citizens of Mexico or certain Caribbean countries to do work related to farm labor for a maximum of eight months (Castles, de Haas, and Miller 2014; Government of Canada 2016; Massey and Brown 2011). The Canadian government expressly stipulates the role of the foreign country to recruit and maintain a pool of qualified workers, ensure that workers have the proper documentation, and appoint representatives to assist foreign workers in Canada (Government of

Canada 2016). Because of the nature of the program, many of the participants are repeat migrants (Massey and Brown 2011).

The SAWP is extremely effective for employers looking to hire migrant laborers (Hennebry and Preibisch 2012), but it is far from ideal in terms of migrant rights. Castles, de Haas, and Miller (2014) specifically note its failures in terms of migrants' social and political rights as a result of the controlled circumstances under which migrants work, themes likewise highlighted by other critics of the program (e.g., Basok 2007; Preibisch 2010). While Canada presents itself as a very multicultural society, touting that over one in five people in Canada is foreign born (Chui and Flanders 2013), the origin of this migrant population is different from the countries of origin specified in the SAWP, suggesting that the connection between Canada and SAWP countries is purely economic. This point is further demonstrated by a December 2017 report by Canada's House of Commons Standing Committee on Agriculture, which offers 21 food policy recommendations, none of which relate to the livelihood of foreign workers, who are instead discussed as a commodity Canada needs (Finnigan 2017). Investigative pieces have also highlighted the struggles of SAWP laborers, demonstrating how many experience food insecurities, poor working conditions, and minimal pay (Weiler, McLaughlin, and Cole 2017b; MacLean Wells and McLaughlin 2018). The SAWP amplifies the power disparity between bosses and workers, as workers are afraid to complain because they might get fired and deported (Weiler, McLaughlin, and Cole 2017b). Though the SAWP has received widespread praise, the major benefits of the program are limited to the economic gains of employers.

As a result of the SAWP, Mexican workers in particular have become a major source of agricultural labor in Canada, with the number of Mexican agricultural workers granted authorization to work in Canada jumping 112% between 1994 (when the North American Free Trade Agreement, NAFTA, came into effect) and 2001. As of 2012, approximately 27,000 Mexican workers come to Canada through the SAWP every year. Although this population is significantly less than in the United States, it still makes up a large part of Canada's agricultural labor force (Weiler, McLaughlin, and Cole 2017a).

Stunningly, 98.5% of SAWP workers finish their contracts each year, 80% are repeat hires, and almost none stay illegally after their contract expires (Mueller 2005; Preibisch 2007). Compared with an estimated 70%

of Mexican agricultural workers in the US without legal documentation, Preibisch (2007) found in a 2004 study that only about 15% of rural agricultural workers in Ontario were working without visas. Part of the reason for these trends is the characteristics of workers recruited to the SAWP with regard to marriage, number of children, education, and experience (Massey and Brown 2011). However, a better explanation for this trend is the benefits the migrant laborers receive from the SAWP.

Although there are certainly clear workers' rights issues—such as forced saving schemes, no path to permanent residency, and an enforced lack of mobility (Hennebry and Prebisch 2012)—Mexican farmworkers in Canada have significant advantages over their counterparts in the United States. Temporary SAWP workers in Canada earn 9.3% more than legal temporary agricultural workers in the United States (Massey and Brown 2011). For undocumented workers in particular, the gap is even wider: legal SAWP workers in Canada earn about 29% more than undocumented workers in the United States (Massey and Brown 2011). Additionally, the SAWP partially pays for workers' transportation costs, provides free housing, and virtually guarantees job contracts (Basok 2000). In early 2019, the Canadian government announced a plan allowing immigration officers to issue open work permits to temporary foreign workers who can prove they have been abused by their employer, addressing the serious issue of workers being tied to one employer who can take advantage of them and terminate their work permits (Keung 2019). For all these reasons, Massey and Brown (2011, 130) find that "once embedded in the Canadian system, [Mexican agricultural workers] tend to return to Canada and do not look upon the United States as an alternative. … In other words, Mexicans appear to shift from American to Canadian migration but not vice versa." This is clear evidence that Mexican agricultural workers find the Canadian temporary agricultural worker program more favorable than that of the United States, even with its own drawbacks.

All this suggests that the United States is much more likely than Canada to experience labor shortages related to temporary migrant labor, and Mexican labor in particular. Indeed, the increasing political and social threats migrant workers face in the United States may divert some of these workers into the Canadian system. We might therefore expect to see different trends in HR weed management given the difference in the two countries' relative access to the hand labor of temporary Mexican agricultural workers. To

investigate this trend, and specifically US farmers' experiences, opinions, and perceptions, we analyzed data from 10 focus groups with commodity crop farmers from four states.

Methods

Data analyzed in this chapter were collected as part of a larger research project funded through USDA-Agriculture and Food Research Initiative grant no. 122422 on "Integrating Human Behavioral and Agronomic Practices to Improve Food Security by Reducing the Risk and Consequences of Herbicide-Resistant Weeds." Between February and May 2015, 10 focus groups with corn and soybean growers were conducted. This population has traditionally had minimal reliance on hired labor; however, the corn and soybean industries are particularly reliant on herbicides and thus are threatened by HR weeds. Two focus groups took place in Arkansas, four in Iowa, two in Minnesota, and two in North Carolina. Hereafter, focus groups are referred to using the state abbreviation followed by a number signifying chronological order (e.g., MN1 signifies the first Minnesota focus group).

Focus groups had between 6 and 10 participants each, as recommended by Morgan (1997), for a total of 64 participants in the study. Table 6.1 presents a summary of participant demographics by state. While the sample misses some of the diversity of US farmers—such as small farmers and minority farmers—it does reflect the majority experience of US commodity grain crop growers. After an icebreaker question, three consistent lines of open-ended questioning were employed: (1) How should/would a farmer react to HR weeds on their own farm? (2) How should/would a farmer react to HR weeds on their neighbor's farm? (3) Is herbicide resistance a short-term or long-term problem?

Following Saldaña's (2015) technique, an emergent coding process was used to identify themes arising naturally from the focus group discussions. Coding of focus group data was completed in three phases following transcription. First, emergent themes were identified by in-depth reading of each transcript. Second, themes were coded into categories while noting representative quotations in the form of statements and conversations. Finally, the transcripts were recoded with the main themes in mind—one of which was labor. Other main themes included techno-optimism and

Table 6.1
Demographics of focus group participants by state

	Minnesota	Iowa	North Carolina	Arkansas
Number of participants	16	25	11	12
Males	16	23	11	12
Females	0	2	0	0
Age	32–68	33–77	44–79	24–73
White	16	25	8	11
Nonwhite	0	0	3	1
Acres managed	200–6,200	110–6,000	0–1,600	2,200–9,200
Acres owned	0–2,600	0–1,500	0–900	40–2,200
Farms with partner	12	18	5	10
Grows corn	16	25	8	9
Grows soybeans	16	25	10	12
Grows cotton	0	0	0	8

individualism, which are addressed elsewhere (Dentzman, Gunderson, and Jussaume 2016; Dentzman and Jussaume 2017; Dentzman 2018). Subthemes and representative quotations were then identified.

Findings

Although we did not specifically ask focus group participants about labor struggles related to HR weeds, they consistently brought up this theme on their own. Specifically, the farmers mentioned how difficult it is to find laborers, the increasing need to employ temporary migrant workers to hand weed, and the high cost of employing these workers. In Iowa, growers mentioned labor as a significant issue impacting their ability to control weeds physically.

IA2

PARTICIPANT: And then, you've got the issue about labor, which is a major problem here in Iowa for agricultural endeavors.

Specifically, focus group participants in Iowa mentioned their inability to find laborers to hoe HR weeds out of their fields. Additionally, several growers

in North Carolina witnessed fellow farmers hire migrants to pull weeds when they had never done so in previous years, a change they attributed to growing problems with HR weeds such as pigweed (*Amaranthus palmeri*).

NC2

PARTICIPANT 1: They was—beans were probably about that tall [holds hands roughly 6 inches apart]. And the pigweed's about that tall [holds hands roughly 12 inches apart]. And they had a group of Mexicans going through and pulling them up. It was right there on the 38, before you get to Springville. But that had to be labor intense, but—

PARTICIPANT 2: —at least he was pulling them up.

PARTICIPANT 3: Looking at bean process, it don't take many hours pulling weeds before it becomes, I guess, economically inefficient. —

PARTICIPANT 1: Cost prohibitive.

PARTICIPANT 3: —having to go out there and pay somebody to pull weeds up.

PARTICIPANT 1: But that's the first time I'd ever seen them do it. But this farmer, he was doing it.

In this discussion, growers directly referenced the newness of seeing Mexican laborers in a soybean field pulling HR weeds. Before the widespread occurrence of these weeds, such laborers would have been unnecessary. Now, even though they were sure it must be costly, growers recognized the increasing importance of foreign temporary agricultural workers to soybean production as a result of herbicide resistance. For the first time in a long time, successfully growing soybeans required hiring migrant workers.

When discussing the specifics of labor shortages, our focus group participants frequently concentrated not only on the *need* for migrant workers but also on the *availability* of migrant labor for HR weed control. In the following discussion in Minnesota, several growers explain how the supply of migrant labor is dwindling.

MN2

MODERATOR: Do you think that's going to be an increasing problem?

PARTICIPANT 1: Labor—

PARTICIPANT 2: Sure seems like it is.

PARTICIPANT 3: —always is.

PARTICIPANT 1: Yeah.

PARTICIPANT 2: Sure seems like it's always a… I mean, we went from—we went from… We would have probably 25 part-time laborers, you know, before round up sugar beets that came up—I mean, they moved—they came up from Texas or Mexico or wherever they all came from, and that—they're not coming anymore. Those people aren't out there to do that.

This discussion reflects the reality that migrant laborers are decreasing in availability in the United States right as commodity grain crop growers are starting to need to hire them (Charles 2017; Fan et al. 2015). In addition to this issue of availability, growers in our focus groups were also concerned with the cost of hiring migrant workers.

NC1

PARTICIPANT 1: Sitting on the porch, you make more than you can out there pulling weeds. I mean it's just so expensive to hire people to pull the weeds. I mean, I do it in tobacco, but that's terribly expensive.

PARTICIPANT 2: Yeah.

PARTICIPANT 3: It cost me $25,000 one year, pulling weeds, just pulling weeds.

AR2

MODERATOR: How much y'all spend each year on hoeing [HR weeds in corn]?

PARTICIPANT: I don't know. To be honest, he says every year, we're stopping at $100,000, and we've chopped about a month past that every year.

These two examples show just how serious a cost it is for growers to hire laborers to hand remove HR weeds. Although the participants believed that the cost was in a sense "worth it," it is doubtful that such an expense will be sustainable for the majority of farms in the long run. Both the availability and cost of labor look to be increasingly significant barriers to physical management of HR weeds. According to Friedland and colleagues (1981), this should result in a movement toward technological and mechanical innovation in weed control.

In contrast to Friedland's theory, mechanized innovations to alleviate labor shortages related to HR weeds have been minimal in the United States. Growers instead tend to pin their hopes on chemical technology solutions.

MN1

PARTICIPANT: I think we're going to have to find chemicals.

IA2

PARTICIPANT: I think we're all hoping somewhere in that chemistry, there's something that comes around that's a new version. Yeah, stall long enough, maybe they'll figure something out, give us another product. That's about it.

Rather than mechanization, growers were hoping for future chemical innovation to provide labor savings in the face of herbicide resistance. However, chemical solutions are becoming few and far between. It takes up to 10 years to develop and release a new herbicide mode of action, and experts believe that there are few new herbicides left to discover (Livingston et al. 2015). This leaves commodity grain crop growers in a paradox: labor is becoming increasingly necessary while simultaneously becoming more scarce and expensive, yet the producers of the chemical herbicides they have come to rely on to avoid labor problems are offering no new solutions.

Discussion

Our focus group discussions suggest that migrant labor shortages *are* increasingly relevant to US commodity field crop growers because of the increasing prevalence of HR weeds that must be hand pulled. Although not all focus group participants had hired foreign laborers to pull weeds, they were widely aware of other farmers who had done so. They also had justified concerns over the decreasing availability and increasing cost of such labor. This prompted a continued hope for the development of new chemical herbicide technologies. However, such new technologies have not appeared on the market in over 20 years and are unlikely to do so in the near future (Beckie 2014). This corresponds with Friedland and colleagues' second condition for mechanization in a commodity sector—the economic and opportunity costs of chemical solutions are becoming high enough that

mechanical solutions have a reduced cost in comparison. Additionally, their first condition for mechanization is already being met in the United States, as stringent immigration policies and an ineffective temporary agricultural worker program are blocking the temporary migrant agricultural worker supply (Zahniser et al. 2018). This suggests that as chemical herbicide development continues to lag and become less effective, the US commodity grain industry will undergo a mechanical transformation in HR weed control.

While the US situation seems primed for mechanization of weeding, the temporary agricultural workers program in Canada suggests a different trajectory for its grain industry. Though Canada is also facing the lag in chemical innovation, Canadian farmers are significantly less impacted by shortages of foreign agricultural workers. Following the theory of Friedland and colleagues, we would therefore expect Canadian farmers to continue relying on the relatively stable supply of inexpensive temporary agricultural workers from Mexico and put off a movement toward mechanization. When labor is inexpensive and readily available, a significant systemic change in agriculture, such as the mechanization of weed control, is highly unlikely (Friedland et al. 1981).

In the future, we expect a divergence in HR weed control techniques in the United States and Canada as a result of the two countries' differing attitudes toward and policies for Mexican temporary agricultural laborers. The answer to what comes next in the fight against HR weeds therefore depends on individual countries' policies toward migrant labor. In the United States, the tandem need for and shortage of migrant labor is pushing US grain crop growers toward reliance on herbicide-based innovation for weed control. Such a "solution" does not challenge the current structure of the agricultural system or larger migration policies in the United States. In this sense, it is the simple solution, because it requires no significant departure from current practices. However, this system is breaking down in the face of arrested chemical innovation, and systematic social change—in terms of migration policies and the structure of agriculture and its labor practices—is not being considered as a viable solution. Given the current political climate and the oppressive focus on productivist agriculture (McDonagh 2014), the conditions in the United States seem incompatible with such changes. If the structures of US agriculture and immigration policies are not reformed, the next solution growers reach for may well be mechanical weed

management, which would slightly alter agricultural practices through scientific change yet continue to ignore needed social reform.

In Canada, we are unlikely to see a similar movement toward mechanical weed control. While Canadian commodity grain crop growers also face serious herbicide-resistance threats and a lack of new herbicide development—satisfying Friedland and colleagues' second condition for mechanization—they do not fulfill the first condition. That is, the migrant labor supply is not being blocked or reduced. Thus, the path of least resistance is to avoid undergoing any type of change, whether agricultural or social. However, just because social change is not *necessary* for growers to combat herbicide resistance does not mean that it should be disregarded. The serious and often brushed aside problems with Canada's SAWP present a moral imperative that cannot be ignored. Temporary foreign agricultural workers are not just a commodity, and they deserve the same treatment and opportunities as native-born Canadians. If Canada truly wants to have a model temporary migrant agricultural worker program, it has the opportunity to lead the way by reforming its program with a focus on the human rights of workers. The problem of HR weeds, however, is unlikely to provide an impetus for such change.

Conclusions

According to our focus groups, migrant labor shortages are not only a horticulture problem. Instead, they are increasingly becoming a problem for commodity grain crop growers as HR weeds become a serious issue and herbicide innovation ceases. Although more research is needed, it appears that Friedland and colleagues' theory of labor determining technological change in an agricultural sector is useful for predicting the future of HR weed control in countries with differing migrant labor policies. It also suggests that controlling HR weeds will not be an issue of only agriscientific or only social-scientific change. Rather, the two are inextricably intertwined in the determination of HR weed control practices.

Taking this into account, we would expect a future in which reliance on chemicals is no longer the solution to labor shortages and HR weeds. Instead, we would predict continued reliance on migrant labor in Canada and the development and adoption of a mechanized weed control technology in the United States. However, the potential mechanization of weed

control is currently only in its nascent stage. The only successful mechanical weed management innovation to date is the Harrington Seed Destructor (HSD) in Australia, which attaches to a combine and pulverizes weed seeds in a rotating cage mill (Walsh, Harrington, and Powles 2012). It is not a stand-alone weed management solution but rather can be combined with chemical weed control to delay resistance (Walsh, Harrington, and Powles 2012). Although demonstrably effective at destroying weed seeds, the HSD costs about $240,000 and only two were sold between 2012 and 2014—both in Australia (Jacobs and Kingwell 2016; Walsh, Harrington, and Powles 2012). The HSD is currently unavailable in the United States, although it is predicted to become commercially available in 2019 (Jason Norsworthy, personal communication, July 8, 2017). At this point, it is unclear whether mechanical weed control such as the HSD will be effective enough—and immediate enough—to keep US farmers profitable in the face of rising costs associated with HR weeds. If mechanical solutions are ineffective, this could open the door for farmers and other agricultural stakeholders to start considering systematic social change as a more viable solution to controlling HR weeds.

Both the US and Canadian cases provide opportunities to highlight the problems with their temporary migrant agricultural worker programs. These problems are not only practical but also moral, as with the serious human rights abuses in the programs of the United States and Canada. At the intersection of technology and social forces, new conversations about national immigration policies and the structure of agriculture can potentially flourish. Particularly in the United States, if mechanization of weed control does not provide the hoped for solution to HR weeds, farmers and other stakeholders may find a growing incentive to lobby for change in how agricultural labor is managed. This underlines the fact that addressing herbicide-resistance management is increasingly becoming a technological issue inseparably intertwined with social justice and migration policies. In this light, the future livelihoods of farmers and agricultural workers, as well as the future of agriculture as a whole, depend on our ability to employ an interdisciplinary lens to a multitude of issues in agriculture. Such a perspective must be used to analyze technological and social issues as conjointly constituted determinants of both agricultural problems and possible solutions.

Notes

1. I-9 audits became preferable to workplace raids in the Department of Homeland Security (DHS) following the 2008 US presidential election (Martin 2013). During I-9 audits, DHS agents review employment records and notify employers of any unauthorized workers.

2. E-Verify is a federal program that requires all US employers, regardless of employment sector, to electronically submit employees' information to check their legal status against government databases. It was developed to ensure that only those who are legally permitted to work in the United States can do so.

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