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Farmer perspectives and experiences introducing the novel perennial grain Kernza intermediate wheatgrass in the US Midwest

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Abstract

Kernza® intermediate wheatgrass (*Thinopyrum intermedium*) is a novel perennial grain and forage crop with the potential to provide multiple ecosystem services, which recently became commercially available to farmers in the USA. The viability and further expansion of this promising crop require understanding how it may fit the needs of farmers' livelihoods and the structure of their farming systems. However, no prior research has studied the perceptions and experiences of Kernza growers. The goals of this research were to understand why farmers grow Kernza, how Kernza fits into their systems and identify challenges for future research. We conducted in-depth interviews with ten growers in the North Central USA during the summer of 2017, who accounted for a third of the Kernza farmers in the USA at the time. All farmers had a positive attitude toward experimentation and trying new practices, and they were interested in Kernza for its simultaneous ecological and economic benefits. Kernza was marginal in terms of area, quality of fields and resources allocated in the farm systems, which also meant that farmers maintained low costs and risks. Growers utilized and valued Kernza as a dual-use crop (grain and forage), sometimes not harvesting grain but almost always grazing or harvesting hay and straw for bedding. Weeds were perceived as a challenge in some cases, but Kernza was valued as a highly weed-suppressive crop in others. Farmers requested information on optimal establishment practices, assessment of forage nutritive value, how to maintain grain yields over years, weed management, markets and economic assessment of Kernza systems. These results agree with other cases on sustainable practices adoption showing that engaging farmers in the research process from the beginning, identifying knowledge gaps and testing management alternatives are critical for the success and expansion of novel agricultural technologies.

Introduction

The global environmental degradation resulting from industrial agriculture generates concern among farmers, consumers and policymakers (FAO, 2011). An implicit aspect of the current global agricultural system is the dominance of annual grains, such as maize, rice and wheat, which account for the majority of the world's diet and occupy the majority of global croplands (Monfreda *et al.*, 2008; Awika, 2011). Yet, the practices accompanying annual grain agriculture bring environmental and social problems (Pimentel *et al.*, 2012). Heavy input use and periodic lack of soil cover generate water pollution and soil erosion, especially on marginal lands with erodible slopes or degraded soil (Blanco and Lal, 2008; Durán Zuazo and Rodríguez Pleguezuelo, 2008; Dalin *et al.*, 2017). The dependence on external inputs (fertilizers, pesticides, fuel) of conventional annual monocultures is associated to socio-economic problems including increased financial costs for small farmers and health impacts on consumers (Sands and Westcott, 2011; Panagos *et al.*, 2018). Responses to these problems have at-large consisted of piecemeal changes to the annual agriculture system, such as cover crops, conservation tillage, proper fertilization rates and timing, etc. However, prominent agroecologists have suggested that this annual monoculture paradigm is the root of the problem (Jackson, 1980).

Perennial grain polycultures have been proposed as an alternative paradigm to bring the regenerative aspects of natural ecosystems to agroecosystems (Cox *et al.*, 2002). Diverse polycultures can provide more ecosystem services such as provisioning (e.g., grain and forage productivity), regulating (e.g., weed suppression, stability), among others, than monocultures (Picasso *et al.*, 2008, 2011; Picasso, 2018). Perennials, lasting beyond one season, need only one pass of the tractor to plant the seed for production throughout multiple years (Glover *et al.*, 2010; Kane *et al.*, 2016). Through their continuous plant cover—both above-ground and below-ground—perennial grain crops have the capacity to decrease soil erosion, increase soil health, prevent nutrient run-off, reduce pollution, lower fossil fuel consumption and mitigate the agricultural contribution to climate change (Glover *et al.*, 2010; Culman *et al.*, 2013;

Gonzalez-Paleo et al., 2016; Jungers et al., 2019). The organic matter provision, soil stabilization and ability to draw nutrients from greater soil depth characteristics of perennial grains make them distinctly-suited candidates to grow in and restore marginal lands, holding special significance for the most vulnerable farmers (Glover et al., 2010).

Kernza intermediate wheatgrass (*Thinopyrum intermedium*) is the first commercially available perennial grain, a cool season perennial grass with relatively large seeds, similar to wheat. Kernza is grown, harvested and sold by select growers throughout the North Central and North Eastern regions of the USA, particularly the Midwest. Demand for Kernza started from one food company (Patagonia Provisions) who developed the first Kernza beer, Long Root Ale, brewed with 15% Kernza grain in 2016 and it has been the main buyer (Peters, 2019). Market interest has exceeded the supply, as small local and organic artisan bakeries and farm-to-table restaurants turn Kernza grain into breads, crackers and pasta (Broom, 2019). With the release of General Mills' Cascadian Farm Kernza Cereal limited edition fundraiser in 2019, the demand for and publicity around Kernza is on the rise, and more farmers are looking to plant Kernza in their own fields (Charles, 2019). In order to obtain Kernza seeds, farmers have to register and sign a trademark agreement with The Land Institute. Some farmers grow Kernza under commercial contracts with Patagonia, which payed a fixed amount per unit of area planted. Other farmers may be part of research contracts with universities to grow and evaluate alternative management practices on Kernza fields.

Plant breeders and agricultural researchers promote crops or cultivars on the basis of the potential of their distinct agronomic characteristics. However, in order for a novel crop to claim a significant portion of the agricultural landscape, its agronomic benefits must fit into the larger picture of agricultural systems, farm systems and their farmers. Examples from the literature are abundant on the need to include farmers' perspectives for the adoption of new crops or practices, including perennial forages (Olmstead and Brummer, 2008) and cover crops (Basche and Roesch-McNally, 2017). Kernza is unique in that its promoted agronomic characteristics relate to its potential environmental benefits. Still, Kernza production could fail if it does not engage farmers (Farrington and Martin, 1988; Leeuwis and Van Den Ban, 2004). Farmer engagement and understanding is especially critical for a novel crop like Kernza, where it is simultaneously still in development while also beginning to be commercially grown. Much remains to be understood about the viability of Kernza as a crop and its fit into the farm system. A few research publications have assessed perennial grain potential utilizing farmer subjects *interested* in growing perennial grains, but not farmer subjects actually growing them (Adebiyi et al., 2015; Marquardt et al., 2016).

Research-based evaluation of the successes or challenges faced by the farmers growing Kernza is needed. At this stage, the first Kernza growers take high risk in growing the new crop, since much is still yet uncertain about best growing practices for optimized and enduring yields, including regional specificities and ideal equipment/infrastructure needs (Ryan et al., 2018). These farmers' experiences growing Kernza now could significantly shape the viability for the expansion of Kernza growth into the future. This research thus seeks to compile and synthesize practical information about the farm-based practice of growing Kernza, as expressed by the farmers themselves. Therefore, this research asked why farmers grow Kernza, how Kernza fits into their systems and which challenges merit future research.

Methods

The methodology for this research involved semi-structured, in-person interviews of Kernza farmers in the US Midwest. The interview questioning focused on (1) basic farmer demographics and farm characteristics, (2) why the farmer decided to grow Kernza, (3) the management practices the farmer utilized to grow and harvest Kernza, (4) the farmer's perceptions of positive and negative aspects of growing Kernza, including agronomic, economic and social aspects, (5) questions/uncertainties on Kernza production and farmer's information needs (Table 1).

Ten interviews were completed with Kernza farmers. Participants were identified through the official registry of Kernza growers, i.e., the list of farmers who have a trademark agreement with The Land Institute to market Kernza, which it was coordinated (at that time) by a small broker company named Plovgh (http://www.plovgh.com). Since 2018, the number of Kernza farmers, commercialization activities and seed supply demands has significantly increased, and The Land Institute hired a full-time person to coordinate markets and seed supply. At the time of conducting the research, this registry included 36 farmers, four of whom had not started growing Kernza yet. The research sample size thus represented approximately 31% of the identified Kernza farmer population. Farmers were selected based on the feasibility of conducting the in-person interview (distance to Madison and the availability of the farmer to meet during the summer). Interviews took place in-person at each farm during June and early July of 2017. The ten on-site visits, each lasting about 2 h, also enabled the collection of observational data about each farm's physical characteristics and socio-familial dynamic, and its Kernza field condition. The four first-year farmers, who had not had their first opportunity for Kernza harvest in July 2017, were contacted for follow-up interviews in April 2019 in order to ascertain their perceptions about Kernza harvest. One of the four first-year farmers could not be reached for a follow-up interview. All interviews followed the approved Institutional Review Board (IRB) protocol.

A grounded theory qualitative approach was used for analyzing the interviews (Charmaz, 2003; Blesh and Wolf, 2014; Orne and Bell, 2015). An in-depth literature review on adoption/diffusion of innovations and critiques for environmental innovations (e.g., Beal and Rogers, 1960; Padel, 2001; Rogers, 2003; Simin and Jankovic, 2014; Adebiyi et al., 2015) informed the development of the questions and interpretation of the data. All interviews were recorded, transcribed and then coded to identify main themes. An iterative coding approach was utilized until reaching the point of saturation, defined as the point when new themes cease to emerge (Charmaz, 2003; Orne and Bell, 2015). The Results and discussion section starts with the demographics and farm characteristics. Then the emerging themes identified are presented: (1) farmer motivations for growing Kernza (innovation, environmental and economics), (2) growing Kernza 'in the margins', (3) agronomic issues (i.e., grain harvest, forage uses, weeds, soil health and establishment) and (4) economic issues. These themes are explained and made transparent through the inclusion of direct farmer participant quotes (Prokopy, 2011; Roesch-McNally et al., 2018).

Results and discussion

Farmer demographics and farms description

The ten farmers who participated in the research were geographically located throughout the US Midwest, with farms in Illinois,

Table 1. Semi-structured interview outline

Demographics and farm characteristics	Age, gender and years of experience farming
	Acres farmed, crops/livestock on the farm
	Conventional or organic practices
	Farming as primary or secondary income
	Size of farm workforce
	Years of experience growing Kernza
Motivations	How did you decide to start growing Kernza?
	What role did you envision Kernza playing in your farming system (function, location/scope on farm, economic role)?
	What advantages and disadvantages did you foresee in growing Kernza?
Management	How do you manage your Kernza agronomically: soil preparation, establishment density, weed control, fertilizers, pesticides, diseases, harvest time, forage use, termination, intercropping?
	How do you harvest your Kernza? How much does your Kernza yield? What do you do with Kernza post-harvest?
	How many seasons has it produced?
	To whom do you sell it? How much do they pay? for what do they use it?
	Economic gain or loss? Inputs *vs* outputs?
Perceptions	How does Kernza actually fit in your current farming system?
	What advantages and disadvantages have you experienced with Kernza?
	What do other farmers say about you growing Kernza?
	What would you tell other farmers who are interested in growing Kernza?
Uncertainties	What issues would you like Kernza research to address?
	What information do you need?

Wisconsin, Minnesota and Iowa (Fig. 1). All participants were male, ranging from 30 to 81 yr old, and had 7–62 yr of farming experience (Table 2). All participants grew up farming, so differences in years of farming experience were a result of age and time spent away from the personal farm. Eight of the ten growers cited their farm as their primary source of income. All but one farmer had diversified farm operations and viewed farm diversity as part of their long-term financial resilience (Table 2).

The average area of Kernza per farm was 6 ha (Table 2). Total area of Kernza production in the USA was approximately 87 ha in 2014 and doubled to 170 ha in 2016 (E.M.G. Haucke, Plovgh, *com. pers.*). Therefore, the area covered by the farmers interviewed (57 ha) represented a third of the total US area in Kernza at the time. Four participants were new Kernza growers, having planted their first Kernza stand in fall 2016 and not having reached their first harvest period by the time of the farm visit and interview, so follow-up interviews were conducted again in spring 2019. Six participants were experienced Kernza growers, with stands of 2–6 yr old. All farmers were growing their Kernza either certified organic (on organically-certified land, all organic farmers and some mixed farmers) or transitional (not certified land but without non-organic inputs, all conventional and some mixed farmers, see Table 2).

Farmer motivations: innovation, environment and economics

Why have farmers decided to grow Kernza despite the current agronomic and market uncertainties surrounding the crop? Kernza growers' attitude toward risk and uncertainty was nuanced. Farmers described the multiple uncertainties involved with Kernza as a disadvantage of growing the crop. Despite this, farmers did not frame it as a deterrent to their adoption of Kernza. Rather, the uncertainty is the other side of the coin of an explorative approach to farming. All Kernza farmers expressed a positive attitude toward experimentation and trying new practices (which can be defined as innovation), underlying their interest toward the introduction of Kernza on their farms, as evident in farmers' quotes:

> 'It was just another opportunity to try something a little different and see what's out there. (…) We're always interested in looking at something different that might be beneficial.'

> 'I guess I was just interested in something new, looking to try something different.'

> 'The unknown is the pioneer part of me. We came here in the great migration of the 1600s so we're all about trying something new.'

> 'I don't believe there's been a year since 1959 or 1960 that I haven't grown some specialty crop or contract type crop. We've always been on that edge. Consequently, this was just another little step in the game.'

Environmental ethic was a strong motivation, either implicitly or explicitly, for six growers, who extended their ecological concerns beyond their own land outward to the larger landscape. All interviewed farmers brought up Kernza's long roots and their potential benefit to the soil, enhancing health and decreasing erosion—a potentially economical method for improving their farmland. At the same time, farmers frequently mentioned in their environmental motivations hand-in-hand with their economic ones (i.e., niche markets for 'sustainable' crops). It thus becomes difficult to delineate farmer motives as practical *vs* idealist. Kernza grower motivations range along a spectrum of

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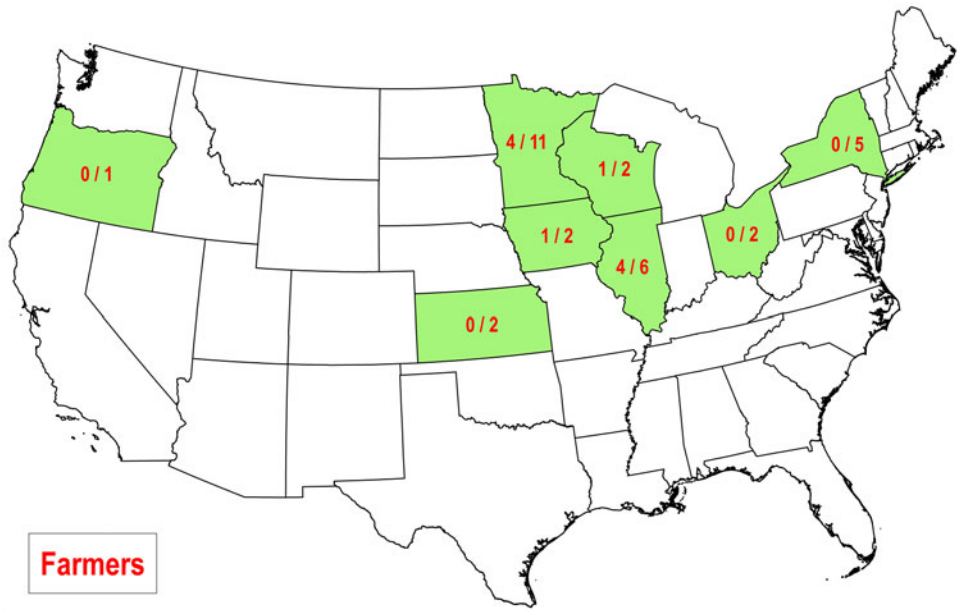

Fig. 1. Geographic distribution of Kernza farmers: number of farmers interviewed per state, (top), and the total number of farmers growing Kernza from the official trademark agreement registry (below).

coexistence where the practical and the ideological operate together. This is perhaps exemplified by the consistent critical reflection of Kernza growers on the historical decline of rural population and communities (Johnson and Lichter, 2019). The paradigm-shifting potential of Kernza represents the possibility of more sustainable rural communities, which serves the interests of the environment and of society at-large and of farmers trying to hold onto their land and livelihoods.

Growing Kernza in the margins

Kernza is a marginal crop within growers' farm systems. No farmer grew more than 15 ha of Kernza, with the majority growing 6 ha or less. Kernza represents a marginal portion of the growers' overall farm system in terms of scale. When farmers commented on this choice, they explained it was to reduce uncertainty or risk of growing a new crop. According to one farmer,

> 'I wouldn't put a lot of acres in, because we don't really know how to harvest this stuff; we don't know much about the management.'

The farmers who planted the most acres of Kernza had contracts which paid out by acre planted rather than by yield, lowering uncertainty and risk. Furthermore, farmers were advised by researchers at The Land Institute or universities, to initially plant small areas of Kernza as the crop is still being developed.

Farmers also explicitly recognized selecting marginal field sites to plant their Kernza. Field margins, areas difficult to access with field equipment and fields with an irregular shape, uneven topography or poor soils were frequent locations for Kernza fields—in other words, locations that, as one farmer put it, 'did not lend (themselves) to row crop production'.

Additionally, farmers admitted that Kernza was often planted in fields with high weed banks. For example, one farmer planted his Kernza into a field which he knew contained 'persistent' brome and reed canary grass. One farmer's statement that:

> 'honestly, it's going in areas that are not of prime production for us, so it's a small part of the operation, a part of the operation that we are willing to sacrifice to experimentation'

reflects the general sentiment of interviewed farmers about their decision-making process on Kernza location on their farms. This was consistent with expectations from annual grain farmers reported by Adebiyi *et al.* (2015) that said they would plant perennial grains on under-utilized or marginal fields.

Also, Kernza management was repeatedly a low priority in terms of growers' allocation of labor and time. Farmers focused their resources on the more secure crops in their farm systems. Farmers used their existing equipment rather than buy new equipment to best suit the specificities of Kernza seed. Depending on the crops they were already equipped to handle, this hindered some farmers and suited others. One farmer summarized:

> 'we've already got the equipment that can handle the stuff. It's a specialty crop. It's a lighter seed than most. Other people aren't used to that. But our equipment can already handle that, so we don't have to invest in new things… And it fits with our operation. We've got cleaning facilities that can handle it. It just seems like it could be a great fit if it really takes off more.'

The lack of investment extends beyond equipment to inputs. Half of the farmers interviewed applied fertilizer inputs to their Kernza fields (Table 2): organic fertilizers (one used left-over compost, other two left-over cattle manure and the two commercial contracted growers used purchased turkey manure). Additionally, Kernza is also a marginal part of growers' operations at the time of harvest. From year-to-year, farmers were inconsistent in their utilization of Kernza's potential outputs, some years harvesting grain, others forage or both (Table 2).

The observed marginality presents distinct opportunities for growers. When farmers do utilize Kernza's outputs, they do so with little to no inputs of pesticides and fertilizers, reducing both cost and labor (Table 2). Further, Kernza's marginal role combined with its unique traits gives it the ability to fit into gaps in the farm system. Farmers viewed Kernza as a tool for areas where more standard crops would not be suited or would produce lower yields, such as rolling land, riparian buffers, edges of fields or otherwise 'marginal' land:

> 'The economics of it, if you're in rolling land, marginal land, (is important). We're sitting on land here that was selling a couple years ago for

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Table 2. Demographics of the farmers, farm characteristics and agronomic management practices of Kernza growers interviewed: identification (arbitrary number, #), age, years of farming experience (Exp), farm management type (type: conv, conventional; org, organic; mix, mixed: areas of organic and conventional), region where the farm is located (Reg: N, northern MN; C, southern MN; WI, northern IA; S, IL), farm area (ha), area certified organic or transitional (org area, ha), number of crops (crop #), presence of livestock in the farm (cattle), estimated size of workforce in full time employees (FTE) including the farmer, whether farming is the main income (inc), first year when Kernza was planted (start), years of experience growing Kernza (Yr), area of Kernza field (K area, ha), market for Kernza (Mark: CG, contracted grain; CR, contract for research; GnoC, grain without contract; FB, forage/bedding), planting date (Plant Date: E, early third; M, mid third; L, late third of the month; Aug, August; Sep, September; Oct, October), planting method (Plant Met: B, broadcasted; D, drilled), inputs applied (input: CM, cattle manure; TM, turkey manure; HM, hog manure; Com, compost), harvest method (Harv Met: DC, direct combine; Sw, swathing), observed weed species (weeds: P, perennials; W, water hemp; T, thistle; C, clover; R, red clover; S, sweet clover; K, Kentucky blue grass; V, hairy vetch)

#	Age	Exp	Type	Reg	Farm area	Org area[a]	Crop #	Cattle	FTE	Inc	Start	Yr[b]	K area[a]	Market	Plant date	Plant met	Input	Harvmet	Weeds
1	81	62	Mix	S	850	**405**	4	Yes	5.0	Yes	2016	2	**4**	CG, FB	L-Oct	B	CM	DC	–
2	65	8	Conv	C	223	0	2	No	2.0	Yes	2016	2	3	CR	M-Oct	D	No	Sw	P, T, W
3	76	54	Org	S	>800	**All**	7	Yes	2.2	Yes	2011	6	**11**	CR, FB	E-Sep	B	Com	DC	–
4	56	35	Conv	N	4047	15	5	No	2.5	Yes	2014	3	15	CG	L-Aug	D	TM	Sw	P, C, K
5	30	8	Conv	N	202	6	4	No	2.5	Yes	2014	3	6	CG	L-Aug	D	CM, TM	Sw	P
6	56	30	Mix	S	65	**20**	5	No	1.0	No	2016	1	**6**	GnoC	E-Oct	D	No	n/a	–
7	61	53	Mix	S	486	81	4	Yes	2.5	Yes	2016	2	6	FB	L-Sep	D	No	DC	R, S
8	36	12	Org	C	142	**All**	7	Yes	1.5	No	2015	2	**3**	CR, FB	L-Oct	–	No	n/a	T, S
9	76	45	Org	N	162	**All**	4	No	1.0	Yes	2011	6	**1**	CR, FB	L-Sep	D	HM	Sw	T, H
10	60	>30	Org	C	130	**All**	5	Yes	3.0	Yes	2014	3	**0.5**	CR, FB	M-Sep	B	No	n/a	–
Av.	60	34					4.7					3	6						

[a]Values in bold are the organic certified area.
[b]Farmers who started growing Kernza in 2016 had not been able to harvest Kernza grain by the time of the first interviews (summer 2017), so they were interviewed again in April 2019 regarding their experiences harvesting Kernza.

> \$9000 to \$10,000 an acre. That's an expensive place to put something that could be on a highly erodible land or a marginal land that shouldn't be in row crop. (Kernza) fits perfectly there.'

One of the advantages farmers most frequently experienced growing Kernza was the decrease in the work of planting year after year and regularly passing the tractor through the field for tilling. This is a critical factor at decisive dates in the growing season, particularly planting, when farmers attempt to balance high time and labor demands from multiple main crops simultaneously. As observed by one farmer, 'the advantage is like for other perennial crops…It's seeded in the year prior so it's one less thing you have to do in the spring.'

Another grower elaborated:

> 'One of the things we do fight around here is the pressure of spring and fall because we do have a very narrow window and so springtime comes and you're wet, so to get out in the field, to do tillage (is difficult)… To be able to move away from tillage, you don't need tractors, you don't have as much equipment. Life is very simple and nice because you don't need all that stuff and you don't need to burn fuel and all this. So there's a lot of advantages that way that you could see in that type of a system.'

Agronomic issues

Establishment

For farmers, some of the most critical agronomic uncertainties related to seeding and stand assessment. One farmer pointed out: 'with Kernza, this is all new, you have no idea. You don't have basic guidance on 'Should I terminate this? Is this an adequate stand? Where am I at?' Another farmer bluntly stated: 'I don't know what constitutes a good stand. Apparently, nobody does.'

Planting late was experienced by all farmer participants and was a clear high point of frustration. Farmers knew that planting should happen by the end of September, but most could not plant then (Table 2). For farmers in the northern region (Table 2), planting should be even earlier. Five farmers blamed the poor stand establishment on the delayed planting. The main reason for planting late was delay in receiving seed supply. Kernza seeds are harvested typically in late July and August, then sent for processing, cleaning and redistribution, and this makes a tight timeline for planting in September of the same year. Seed often did not reach farmers by the time they expected it:

> 'We were hampered this year because of supply delay… We should've had (the Kernza seed) in late September. We didn't get it in until late October.'

> 'So I waited around. I was back-and-forth with (supplier in) Wisconsin, 'Where's my seed? I need to plant this stuff.' Never came, never came, never came. They finally got it here and it was raining and the whole thing—the time was bad. If I had the timing right, I'd have a beautiful field right now, but that's farming. I have an okay field, but I'm going to have to wait 'til next year probably to get a crop out of it.'
> 'Part of it was the (trademark) contract—(coming) late. (Then) the seed not coming 'til late. Just everything happened too late….'

This problem of seed distribution on time for planting is probably related to the initial stages of development of the supply chain. Seed producers are the farmers or researchers at experimental stations, who are both learning to manage this novel crop. It is reasonable to expect that as the crop expands the seed supply and the logistics will be streamlined.

Seeding methods varied: most farmers drilled their Kernza into rows, while three farmers broadcast their seed (Table 2). Farmers who had more experience with growing grasses drilled seeds at a lower seeding rate (due to the light weight) or broadcast. Largely, farmers expressed that, although their seeding methods were sufficiently effective, they were uncertain if their method was actually the best-suited to Kernza, especially with regards to spacing.

Grain harvest

Although grain is the main intended use of Kernza, three out of ten farmers had not harvested a Kernza grain crop (Table 2). Only the two farmers with commercial contracts for grain have harvested every season after planting. Growers had chosen not to harvest due to perceptions of sparse stands, or too many weeds, which could have reduced yields and contaminated seeds. Other reasons for not harvesting were small field size, inconvenient location of the field, not having the right equipment and lack of experience harvesting small grains. One farmer faced several of these challenges and justified his decision not to harvest:

> 'on the harvesting side, that's an issue because the seed is so fine (for) my combine settings—I'd have to buy some other parts to probably put inside my harvester to be able to get that fine seed and not lose it all. It could be done, but for 8 acres, you know, it doesn't hardly make sense… The problem is—if I had my own combine, my own equipment—but I have to pay someone to come do it and if I only get a few hundred pounds, I'm losing a lot of money. It'd be nice to have some seed off it but if I have to do it at a loss, I might as well wait for next year.'

Additionally, the best harvest timing and method (direct combining *vs* swathing) for Kernza are still an uncertainty for farmers. Notably, though, the three farmers who had harvested their grain were confident in their methods due to their prior experience harvesting grass seed crops. A farmer who direct-combined said,

> '(Harvesting's) not a problem. We know how to set a combine… I've harvested orchardgrass and sweet clover, red clover, so that's not a problem,'

while a farmer who swathed demonstrated similar confidence,

> 'general practice is to swathe and let 'em lay in windrows. Dry 'em, bale 'em, and then harvest the crop. As far as timing of swathing, it's kind of based on, you know, ryegrass, bluegrass, other species as far as what they look like.'

Consistently, among all farmer participants, the theme emerged that grain yield matters. This finding is contrasting to the results of Adebiyi *et al.* (2015) and Marquardt *et al.* (2016) who found that perennial grain yield was of low importance to farmers interviewed. Yield matters particularly to farmers in regions where corn/soy cropping systems are dominant and productive. A farmer explained, in relation to his growing area,

> 'Think about the yield around here. We're consistently growing 200 bushel corn (per acre), 40/50/60 bushel (soy)beans (per acre). I mean you're talking about thousands of pounds of grain… Soybean are a couple thousand pounds an acre…So you've got a loooot of production and this Kernza, it's so light.'

In other words, Kernza does not have the appeal of high corn and soy yields. Of concern is not only the quantity of grain but also the size of the grain and the consistency of yield across years. The farmers see Kernza grain as small and light. Especially to those whose main crops are large grains, it is difficult to adapt their mindsets and management practices to Kernza grain's smaller size.

Forage uses

Beyond grain, Kernza biomass can also be used for grazing, forage (hay) and bedding material. Two farmer participants have grazed their own beef cattle on their Kernza and one was planning to graze. Two farmers used Kernza hay as forage to feed to their beef cattle. Three farmers used Kernza for bedding—one gave the Kernza straw to the neighbor who had baled it for him, another sold the straw bales, and another used it as bedding for his own cattle. Few farmers did not use Kernza for any of these three purposes (Table 2). Grazing, hay harvest and straw bedding harvest all occurred regardless of whether the grain was harvested. This demonstrates Kernza's potential dual-use in a single growing season and Kernza's possibly higher accessibility to farmers as a traditional forage crop over as a grain crop. This was also consistent with the expectations from annual grain farmers who emphasized the dual grain-forage potential value of perennial grains (Adebiyi *et al.*, 2015).

Growers' interest in Kernza for pasture or forage varied in whether their farm had livestock, the local supply of forage in their region and their perception of Kernza's forage quality. A farmer whose farm operation included grazing cattle stated,

> 'For us specifically, I think how it performs in the rotational pasture system with maybe a clover-alfalfa, a perennial ryegrass mix, something like that and see(ing) what it's performance level is (Kernza's potential use).'

Farmers without livestock had to find an outlet for their hay or straw and derived less direct benefit from it. A corn–soy farmer lamented,

> 'If I had cattle and I could feed it, (Kernza would fit better on my farm), but because I'm strictly on the grain (harvest) side—and I've also spoken to others about this—it fits better probably in a small organic dairy farm, on an operation where you have equipment. But if you're sitting in a situation where you're doing the corn-and-bean thing, then all those things (having the equipment for forage and the livestock to whom to feed it) now become a problem for you.'

A farmer who consistently harvests and sells his grain noted that his friend's Kernza, which was grazed as well as harvested, 'has a lot more utility for him because of the cattle'.

The same farmer did not consider harvesting his Kernza for forage to sell, because the forage market in his region was saturated and did not consider the forage quality was competitive:

> 'There's so much forage in our area. Especially after you combine it, it's not going to be good forage. There's a lot of better-quality forage to be had out there.'

Farmers satisfied with their Kernza stand's establishment found Kernza's biomass offered an abundant quantity of potential forage. Forage quality was the salient question for the farmers. Farmers judged the quality of forage based on their timing of grazing or forage harvest and how well their livestock appeared to consume the Kernza. In the cases where farmers used Kernza for bedding, the harvest of Kernza biomass in the form of straw took place post-grain-harvest or late in the season, when the forage quality was presumably low. Late-harvested Kernza straw thus was a lower-value use of Kernza but also a convenient use for farmers who already harvested grain or who did not have time to deal with their Kernza in the height of the growing season. Farmers who fed their livestock on Kernza varied in their assessment of their cattle's preference for it, but agreed that forage quality tests were needed to determine their continued and future use of Kernza as forage. As one farmer stated,

> 'we'll send (the forage) to the lab and see what we got. If you're not doing that, then you're flying blind. Just because your calf gobbles it up doesn't mean it's good for them.'

Weeds

The farm-level ecosystem service most frequently highlighted by growers was weed suppression. Three of the farmers cited weed prevention as the main use of their Kernza, while four farmers expressed weed suppression was one of the greatest benefits experienced by growing Kernza. These farmers repeated phrases that Kernza: 'is so persistent and tough'; '(does) not pay attention to any weeds'; 'pretty much squeezes everything else out'. One farmer is promoting Kernza to manage giant ragweed.

However, the storylines which emerged around Kernza and weeds were more complex and contrasting. A frequent message about Kernza was that it could quickly become a 'weedy mess'. Two of the farmers continue to struggle with high weed pressure, while other farmers who were initially concerned with high weed pressure reported decreased weed-to-Kernza ratios after a spring or summer mowing/cutting of the field. According to one farmer who could barely identify the Kernza plants amidst the weeds after planting,

> 'I thought, 'there's too much of this odd-looking stuff for it to be just weeds—that must be what (the Kernza) is. (We) mowed it off and probably within two weeks or so, the Kernza appeared.'

Weed pressure in Kernza was often linked by farmers to factors of the type/condition of the land of the Kernza field and the perceived level of success of initial stand establishment. Farmers who experienced more weed pressure were those who established their Kernza on a field with or near an established weed bank and/or whose Kernza stand established poorly and remained sparse:

> 'It was apparent that I was taking an area that was available and that was a nice place to put (the Kernza), but there was some pretty persistent (weeds), like brome and reed canary grass. There was a lot of really tough stuff there. So I went in and burned it down, but it didn't kill well enough…It wasn't a fair trial.'

Additionally, rather than simply being low or high, or increasing or decreasing, farmers throughout interviews amended their weed pressure characterization to emphasize community composition shifts. All farmers with stands older than 1 yr noted that weed communities in their Kernza field shifted over time from annuals to perennials. This is consistent with the research documenting weed succession changes in other perennial systems such as alfalfa (Meiss *et al.*, 2010) or grass pastures (Hiltbrunner *et al.*, 2008), where perennial weeds increase over the years.

In all cases, farmers' perceptions of their experience with weeds in their Kernza plot were a central point. Farmers who downplayed weed pressure or who saw it as low or decreasing had more positive perspectives on growing Kernza in general. Conversely, farmers who emphasized high or increasing weed pressure had more negative perspectives on growing Kernza. Conventional farmers were especially sensitive to weed presence. Since conventional farmers' ideal is to have a weed-free field, they suffered poor reception from family and neighbor growers who noticed weeds in their Kernza fields. A grower explained,

> 'Older (conventional) growers generally don't appreciate looking out at a field they've farmed their whole life and seeing a bunch of weeds in it. I think, in the organic production, you're going to see more weeds.'

In a previous survey, annual grain farmers predicted that planting perennial grains would increase both their annual and perennial weed pressure (Marquardt *et al*., 2016), which was not consistent with most Kernza growers' experiences. In that study, organic annual grain farmers expressed more concern over weeds than their conventional counterparts, who expected to manage weeds with herbicides (Marquardt *et al*., 2016). In practice, though, conventional-farming Kernza growers struggled with weeds since they were not able to apply herbicides in their Kernza fields due to the fact that there are no herbicides approved yet to use in Kernza intended to human consumption.

Soil health

While grain and forage are the two main commercial uses for Kernza, other ecosystem services are also a relevant output for the farmers. Nine out of the ten farmers found that the supporting and regulating ecosystem services to their land were the main benefit experienced growing Kernza. Farmers agreed over the positive potential of Kernza to deliver ecosystem services, such as soil regeneration, erosion control and nutrient/pesticide runoff prevention. Particularly, farmers couched these benefits within the image of Kernza's deep root system:

> 'It's a great conservation crop and the land it's going on needs that. It's a benefit that by being a solid root mass crop it controls both wind and water motion.'

> 'In terms of that issue of nitrogen, I think a deep-rooted crop could do a lot for catching, or at least preventing, a loss of a lot of this nitrogen.'

> 'I think its capacity to develop root mass is going to be very beneficial for soil-building.'

> 'For me, the benefits are definitely in the roots…There's no loss of nutrients from a Kernza field.'

This is consistent with the expectations from previously interviewed annual grain farmers (Adebiyi *et al*., 2015; Marquardt *et al*., 2016), who mentioned soil quality improvement capacity of perennial grain deep roots as one of the major benefits.

Other agronomic issues

Farmers with older Kernza stands were concerned with the significant grain yield decline after the second year of Kernza harvest. They attributed the lowered productivity to plants becoming '*root-bound*' with increased stand density, as a result of continual tillering. One participant with the oldest stands highlighted dealing with a root-bound stand as a top priority for research. He has already tried to counter decreasing yield through management:

> 'We went in and diced (the Kernza field) up with the no-till drill just to open up or disturb some of the root system and then over-seeded with red clover and the red clover has done very well in it. I think we're just going to leave it and see what we can do with it.'

Other farmers with multi-year stands contemplated taking similar measures, whether mechanically cultivating, grazing or burning. One farmer said,

> 'We've been talking about how to renovate or how to keep it productive for more than—at least what we've seen so far, first year's the best and then we've seen it going downhill. Talking to (a Kernza breeder), he said the inter-row cultivation has gotten Kernza to be productive for more years.'

An additional question for farmers, rather than extending yield longevity, was the possibility of incorporating the Kernza into a crop rotation in which Kernza grew for just 2–3 yr. This prompts another question for farmers—how to terminate a Kernza stand. In fact, two growers feared that Kernza could become invasive. This was a concern also from annual farmers in previous studies (Marquardt *et al*., 2016).

Farmers raised the topic of other agronomic uncertainties with less frequency. Farmers wanted to know whether Kernza could be intercropped, but only one first-year grower was actively attempting to intercrop between his woody perennial crops. One conventional farmer, in particular, was interested either in potential non-organic methods for managing Kernza or more specific organic management guidelines. Besides one exception, farmers were not concerned about managing Kernza fertility, either because they planted their Kernza into fields they expected had a sufficient stock of nitrogen from previous use or they had added manure or compost to the field in a later year of Kernza growth. In terms of pests, only observations were geese disturbance (two farmers) and deer disturbance (one farmer). Ergot was the only disease mentioned and was only mentioned by one farmer. Only one grower brought up lodging as a problem.

Economic issues

All farmers mentioned markets and economics at various points in their interviews. Three farmers expressed that research on Kernza profitability and market infrastructure should be a priority. Another three farmers cited one of the biggest disadvantages experienced growing Kernza was the market and income uncertainty. Farmers were aware that there were bakers and brewers and now General Mills interested in buying Kernza grain at a higher price than other grains due to its growing reputation as a 'sustainable' crop. However, apart from the two contracted growers, farmers were unaware of how much Kernza markets were actually demanding and what price they would receive for the grain. In other words, farmers did not know whether Kernza would be a profitable crop. A grower questioned,

> 'If you look at the market, what would the market price for it be right now? There's bakers and brewers who really want to play with it, yet they're gonna give me a dollar a pound?'

Farmers who envisioned Kernza as a niche crop articulated a confident or neutral stance on the economic potential of Kernza for their farm. Three such farmers even discussed the hope of direct-marketing their own Kernza grain. Another stated,

> 'There's a disadvantage for a person who is looking for dollars of income, but we weren't looking for that—we were looking for balance.'

Farmers who directly compared Kernza to standard row crops, such as corn and soy, articulated pessimism about Kernza's economic potential on their farm. As one grower summarized,

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> 'Really, it comes down to economics. Not only does Kernza need to be profitable, but it probably needs to be as profitable as the best other crop too.'

This is also contrasting to the findings of previous surveys of annual grain farmers who found that most were little concerned with economic and market viability of perennial grain (Adebiyi *et al*., 2015; Marquardt *et al*., 2016). It is thus likely that these are the issues that become of greater focus for farmers once they actually take on the risk of planting perennial grain and naturally come to face its financial realities.

Farmers demonstrated both short-term and long-term thinking around growing Kernza as they described their financial concerns. For example, short-term worries included the current uncertainty of Kernza grain markets and prices, while a long-term fear was that Kernza grain markets could eventually stagnate or become oversaturated. Long-term perspectives impact the way farmers foresee the practical benefit of a perennial crop, such as Kernza. Even though the grain yields of Kernza decline over time, farmers envisioned maintaining a Kernza stand for multiple years of both market diversification and ecological improvement to their farms.

Conclusions

This study aimed to begin to fill the gap in research on the agronomic and economic reality of incorporating Kernza onto the farm. Such research is the key to making Kernza accessible and useful to farmers, which in-turn is critical to enable Kernza's potential to shift the agricultural paradigm. Due to the novel nature of Kernza, it is still surrounded by much agronomic uncertainty. Therefore, Kernza remains a marginal part of the growers' farm systems. Kernza growers are utilizing Kernza for its multiple outputs, less frequently for grain and more frequently as a forage or an ecosystem service provider. Farmers are especially concerned with research questions which address planting timing, dealing with decreasing yields over time and economic and market uncertainty. Kernza is moving into an important phase as it transitions from breeding to commercialization. Farmers are a key part of this transition. The findings presented intend to serve as a baseline for future research. Further studies should continue to incorporate Kernza grower's experiences and perspectives and promote a dialogue between Kernza growers and Kernza breeders, researchers, processors, distributors and buyers.

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