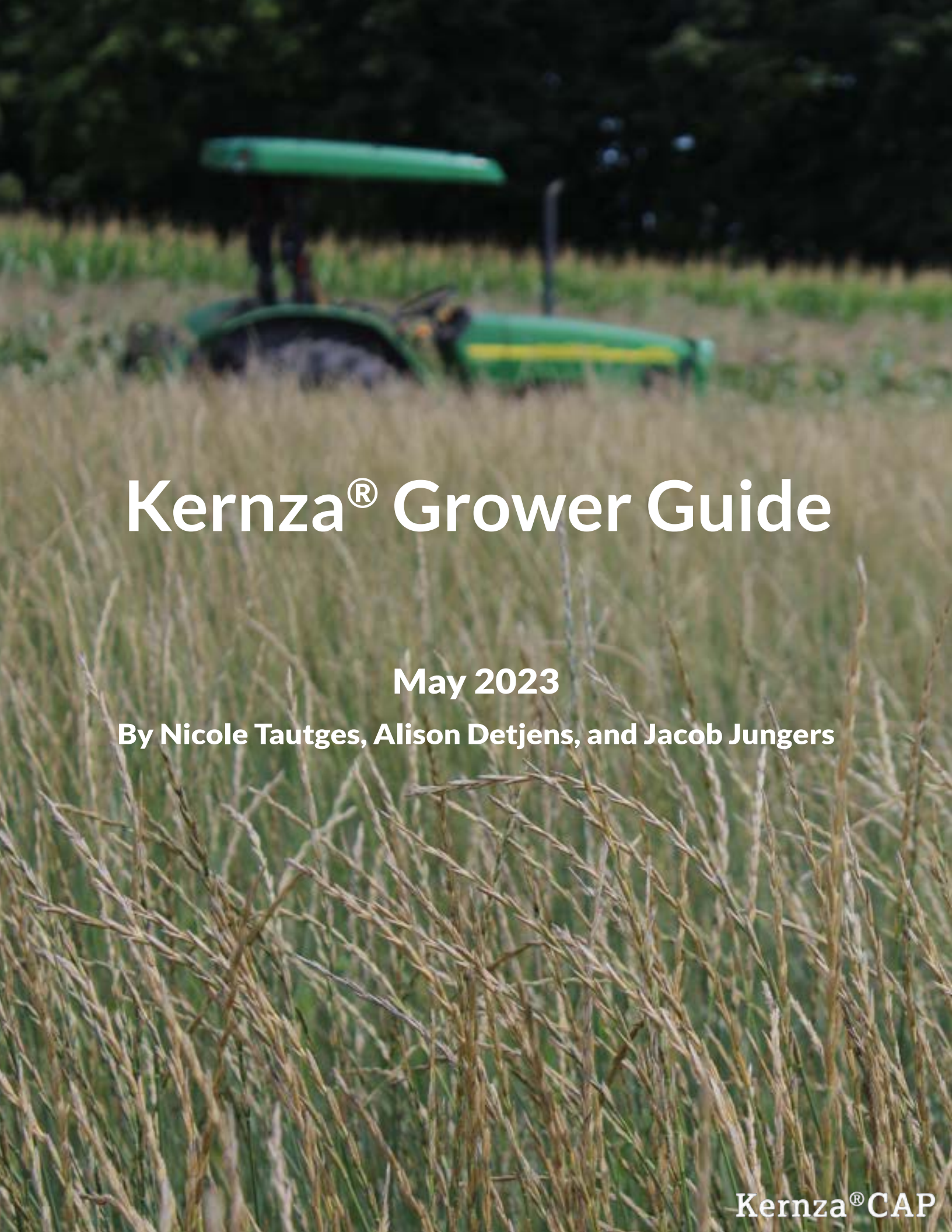

Kernza® Grower Guide

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Kernza®CAP

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Welcome to the Kernza® Grower Guide!

The movement to perennialize agriculture seeks to better protect our surface and groundwaters, keep soil in place, store atmospheric carbon, restore ecosystems, and transform your local landscape - and we're glad you're here. This guide was developed to provide growers with the information they need to grow and store Kernza perennial grain, from rotational planning and planting considerations, to management, combine settings, harvesting, and post-harvest handling. We also provide tips and references for where and how to explore market channels.

Anyone with small grains production experience can establish and harvest Kernza, though there are important differences in methods, which we highlight in the guide. Those who don't already work with small grains may experience a steeper learning curve, but can be successful Kernza growers as well. In either case, there is a Technical Assistance Team you can contact for support (see page i).

Those who grow Kernza quickly realize that they are stepping into a different sort of growing community, one that is communicative, collaborative, and innovative. If you value those principles, you will likely enjoy this new crop and connecting with peers who also care about conservation and rejuvenating rural landscapes. We are just beginning to scratch the surface of potential with perennial grains. Thank you for joining us.

–Yours Perennially, all the authors and those who worked before them.

Colin Crowley, PBS Wisconsin

CHAPTER 1: Introduction

"As we search for a less extractive and polluting economic order, so that we may fit agriculture into the economy of a sustainable culture, community becomes the locus and metaphor for both agriculture and culture."

-Wes Jackson, Becoming Native to This Place

Where did Kernza® come from?

Kernza is one product of the pursuit of perennial agriculture–that is, replacing tillage-based annual systems with diverse perennial systems that produce plentiful food for humans and other organisms. Early work began at the Rodale Institute in 1983, where over 300 species of herbaceous perennials were screened for their potential for crop development. Ultimately, intermediate wheatgrass (scientific name: *Thinopyrum intermedium*) was selected because it had many desirable traits (including best culinary qualities) and was already being used in the United States as a pasture and rangeland grass. Intermediate wheatgrass is related to other wheatgrass species like crested wheatgrass that are commonly used as forage/rangeland grasses, and is a distant relative of wheat and other annual grains.

The Rodale Institute conducted an intermediate wheatgrass breeding program throughout the 1990s, selecting for grain yield and quality improvements. They transferred the germplasm to The Land Institute in 2001. The Land Institute formally launched a Kernza breeding program in 2003, and by 2009 had doubled seed size and seed yield per head. The Land Institute filed the trademark for the name Kernza in 2009 to protect the identity and fidelity of the new improved lines, which would go on to become a released variety.

Kernza is the only perennial grain crop currently marketed in the United States. Genetic and agronomic research and development are ongoing, but it can be found in niche markets nationally. The Land Institute is committed to bringing this crop to scale in a responsible manner, working with growers who understand the experimental nature of the crop. While Kernza was developed from intermediate wheatgrass, Kernza has been optimized for grain production. For those interested primarily in perennial grass forage production, there are many released varieties of intermediate wheatgrass that have been bred for improved forage qualities. It should be noted that Kernza is NOT gluten free.

Kernza® trademark and the Identity Preserved Program

The Kernza trademark and Identity Preserved Program were established to distinguish new and improved Kernza varieties and germplasm. Kernza varieties are released by The Land Institute's breeding program, and are distinct from intermediate wheatgrass that has not been bred for grain production. The Identity Preserved Program also helps track Kernza acreage and grain production to understand regional and national market growth. The Kernza® usage trademark and license to grow both fall under the Identity Preserved Program–they are all regulated under the same process, which is the application form described below.

Licensing

To maintain a license, growers must submit field location, planted area, and production information annually, in response to requests sent by The Land Institute via email and/or phone. For more details, see the Kernza® Identity Preserved Program Guidelines document in the Appendix.

STEP 1: Apply: Complete a Kernza grower application**.** Go to kernza.org/growers, scroll down, and click on the "Apply to Grow Kernza® Perennial Grain" link, and fill out the short web application. Review the "Questions to consider before growing Kernza" section below to help you prepare answers to the application questions.

STEP 2: Review: Conducted by The Land Institute. You will be contacted either for an initial 15 to 30 minute phone conversation or asked to join a monthly call for prospective growers with a TLI representative or close partner to discuss your farm system, post-harvest capacities, and marketing plan. You will also be able to ask any questions you may have. Follow up with the Kernza Technical Providers listed on page i if you have not received a response to your application in one month after submission.

STEP 3 : Approval Notification and Licensing: If you are approved to grow Kernza, you will receive an email from the web software Docusign, requesting your review and signature on the Trademark Licensing agreement. The Identity Preserved Program is also included as an appendix to the licensing agreement. These two documents work with one another to ensure Kernza Perennial Grain is of high quality and that growers contribute basic production data to The Land Institute. Growers must sign and submit these licensing documents before they are eligible to purchase seed. A $5/acre fee is included in the license. You don't have to pay this fee unless TLI invoices you, and you will not be invoiced unless your harvest was successful and you were able to sell your grain.

STEP 4: Buy Seed: Once you have signed the license in Docusign, you will receive a list of approved seed sources. You must use an approved seed source for your first planting of an approved Kernza variety. The Land Institute does not sell seed.

Questions to consider before growing Kernza®

Kernza is a new crop with unique agronomic, post-harvest, and marketing needs. These questions cover some of the main factors that determine success with Kernza. If you can answer yes to most of these questions, Kernza might be a good fit for your operation.

Site and Region

1. Kernza has vernalization (cold temperature) requirements in order to produce a seedhead. Does your region have average daily temperatures between 27 to 50 degrees F for about 4 to 6 weeks?
2. Kernza can tolerate drought conditions but does not tolerate waterlogged soil well. Do you have acreage that is not prone to flooding or waterlogging?
3. How much acreage do you want to try at first? Is 5 acres worth your time, or do you want to go larger-scale and incur more risk at first? Keep in mind that very small and very large lots of grain may be difficult to handle post-harvest without prior experience.

Agronomic Questions

1. Growers who have experience with small grains or grass seed have often found growing Kernza relatively easier than growers who don't have that type of experience. Many other producers have had success with Kernza production as well; it just requires more learning. Do you have experience growing small grains or grasses for seed?
2. Agronomic management techniques are still being developed for Kernza. Are you interested in experimentation with a new crop?
3. Kernza fall forage is generally high quality, so managing Kernza for forage production in addition to grain provides an additional revenue stream. Do you have access to forage harvesting equipment and a forage market?
4. Current markets for Kernza grain are primarily organic. Do you want to grow Kernza organically?
5. Planting Kernza requires equipment for small seeds. Do you have access to planting equipment for small seeded crops (such as a grain drill or a grass seeder and packer)?
6. Harvesting Kernza requires equipment for small seeds. Do you have access to harvesting equipment for grasses or small grains (such as a swather and a pickup head or a stripper header)?
7. It is recommended to remove Kernza straw after harvest (and fall forage, if desired). Do you have access to a baler for removing hay or straw after grain harvest?
8. Post-harvest handling questions
9. Kernza typically requires drying after harvest. Do you have grain bins on site equipped with full floor aeration, or grain dryers?
10. The current market for Kernza requires that growers have on-farm storage; therefore you should have a plan for how you will hold grain in good condition prior to its sale and transportation. Do you have other post harvest equipment and storage infrastructure, including gravity wagons, forklifts, grain totes, or the ability to clean and dehull grain?

Marketing Questions

1. Kernza summer straw and fall forage offer additional revenue streams for Kernza production. Do you have a market or use for forage, hay, or straw?
2. There are no grain elevators or other guaranteed market outlets for Kernza grain. It is best to have a marketing plan in place prior to planting– this includes identifying and scheduling cleaning and dehulling. Do you have experience with direct marketing grain? This could mean reaching out to bakers, restauranteurs, brewers, distillers, etc. (this marketing approach gives you the most control over selling and achieving profitability with your Kernza enterprise).
3. Consider whether you want to join a grower marketing organization (e.g., Perennial Promise Growers Coop in the Upper Midwest, Sustain-A-Grain in Kansas), or do direct marketing yourself. Kernza partners will attempt to assist with grain marketing but make no guarantees for sale. Are you interested in joining a co-op or willing to seek out marketing opportunities on your own?

Kernza in its second spring (foreground) next to a field with a winter rye cover crop (background); illustrating how Kernza can produce soil cover on season shoulders.

CHAPTER 2: Establishment

"One change always leaves the way open for the establishment of others."
– Niccolo Machiavelli

Current breeding programs and available seed

Five major breeding programs are actively developing Kernza, but only two have released varieties: the Land Institute (TLI) in Salina, Kansas, and the University of Minnesota (UMN). Breeding programs at University of Manitoba, USDA-ARS Utah State, and Uppsala, Sweden have not released germplasm yet, but may do so in the future.

Breeding goals include increasing grain yield and threshability (how easily the seed can be separated from the non-edible hull), and reducing seed shattering and plant stature. Given how rapidly germplasm is being improved by the breeding programs at TLI and UMN, it is very important that growers source the newest released varieties when possible. The Kernza Technical Assistance team (contact information on page i of this guide) can be consulted for the latest information on recommended varieties.

Germplasm from TLI has been adapted to semi-arid production regimes, specifically the Great Plains region, but is also adapted to the Northern Great Plains including Montana and Wyoming. The first available Kernza germplasm was "Cycle 5" (C5) from Dr. Lee DeHaan's breeding program at TLI, which has been retired. No new production plantings of C5 should be established as improved germplasm is now available. TLI released five new varieties in 2022 that are recommended for growers in the Great Plains and West.

The UMN varieties are well adapted to humid continental climate types like the Upper Midwest and Northeast regions. UMN released 'MN-Clearwater' in 2019, which is the dominant variety currently being grown in the Midwest. New variety releases are expected in 2023-2024.

Currently there are no varieties available for growers south of Kansas. It is unlikely that Kernza production will be viable in those regions due to its vernalization requirements. Growers should order the variety that is best adapted for their location. Prospective growers can specify a variety choice when applying to become a Kernza grower.

Table 1. Kernza varieties available on the seed market in 2023.

Name	Description
TLI - 3471	Long, slender seeds, higher percentage of naked seed compared with TLI C5.
TLI - 701	Decent performance in drought conditions.
TLI - 703	Higher number of rhizomes compared with TLI - 704, decent performance in drought conditions.
TLI - 704	Drought sensitive. Recommended for wet or irrigated conditions only. Few tillers.
TLI - 801	Higher percentage of naked seeds, consistent despite drought conditions.
MN - Clearwater	Higher percentage of naked seeds, selected under cold, wet spring soils and higher precipitation.

Site selection and suitability

Intermediate wheatgrass (IWG), the perennial grass that underwent breeding and selection to produce grain varieties trademarked as Kernza, is adapted to drought and semi-arid climate types like those of the US Intermountain West. Kernza is better adapted to dry conditions than wet (it does not like "wet feet"). It is not recommended to plant Kernza in low lying fields that flood often or have drainage issues. Particularly in the establishment year, "wet feet" can impact stand survival. Drainage tends to be more of an issue in fields with clay soil types, so soil texture in a field should be considered before planting Kernza. For those farming steep slopes, Kernza's extensive roots can help stabilize soil and prevent erosion. However, as with any crop, growing Kernza on slopes that do not retain water well is likely to decrease grain yields should moisture stress occur. According to a study conducted in Kansas, Kernza uses between 600 and 700 mm (23.6 to 27.6 inches) of water per year, with 80% of water use occurring between May and October (de Oliveira et al. 2020).

Kernza should be planted in fields that are free of perennial weeds and winter annual grass weeds (for example, downy brome, jointed goatgrass, or pennycress), especially west of the Mississippi River. Unlike summer annual grasses, such as foxtail, winter annual grasses compete with Kernza and weed patches will grow within Kernza stands. It can be difficult to separate winter annual grass seeds from Kernza during grain cleaning, so significant presence of these weeds can decrease Kernza grain quality and result in large dockage losses.

Planting Kernza into a field with historically high levels of summer annuals may not result in high weed pressure. Healthy stands of Kernza can prevent germination of these weeds and can likely help mitigate pressure in the long term (though more research is needed on this topic). Fields with a history of perennial grass weeds may not be ideal for planting to Kernza as studies have shown that perennial grass weed populations can increase in fields of Kernza.[1]

Kernza requires certain soil nutrient levels each year to produce a grain crop (at least 80 lb N/acre, and standard P and K levels for small grain production). Notable yield declines will be observed where soil nutrients are not present and/or replenished. Kernza should be planted on fields that have not historically suffered from low fertility. In summary, growing Kernza on sloped fields, fields low in fertility, those susceptible to flooding, or on marginal lands will result in yield declines and is not generally advised.

Kernza should not be planted in areas with poor drainage, following winter annual grain or grass crop, or in fields with high amounts of perennial grass weeds. Do not plant Kernza where you cannot provide proper management as you would for other crops–that includes weed control and fertilization.

Kernza® in rotations

Kernza can fit into a variety of rotations, including as a perennial phase within an annual system, or replacing hay or small grain crops. In the Midwest, an example rotation might be corn-alfalfa-Kernza-soybean-corn. However, planting Kernza after corn for grain and soybeans is often too late for most regions of the US. Kernza establishment

is often most successful after harvesting early season crops, such as spring-planted small grains like wheat, barley, and oats, and broadleaves like buckwheat, dry beans, or peas. Spring planted small grains can either be baled off for forage/silage or harvested as grain. Planting Kernza after winter cereals is strongly discouraged. Volunteer plants can overwinter and compete with emerging Kernza plants. They can also contaminate grain lots since they are difficult to clean out of Kernza.

In the Great Plains and other Western areas, Kernza could replace annual wheat in rotation. Think of Kernza as a perennial forage option that also allows for marketable grain for several seasons (see the Dual Use section on page 29). Oilseeds like canola are an early season crop option to precede Kernza in the West. In the Northern Great Plains and the Intermountain West, Kernza could also follow summer fallow or a summer legume. Whatever the previous crop, remove as much residue as possible (for example by baling off) and practice the stale seedbed technique at least once prior to seedbed preparation for Kernza: clear off previous crop residue, allow time for rain that germinates weed seeds, then till or spray to control weeds. The ability to control a flush of weeds prior to Kernza planting can greatly help limit fall weed pressure in establishing Kernza. Stale seedbed can also help to flush out small grain volunteers which, if heavy in pressure after Kernza has germinated and emerged, can inhibit Kernza stand vigor. Have a plan to control grass volunteers to give young Kernza stands the greatest chance of successful establishment.

Kernza can be established after perennials like alfalfa, red clover, or other legumes. If following alfalfa or established pasture, organic producers should perform heavy tillage to adequately terminate the previous perennial crop to prevent regrowth the following year. Failure to adequately knock back existing perennials can contribute to stand failure. Use deep tillage such as a ripper or chisel plow to create a consistent seedbed. When using a chisel plow to terminate alfalfa, a wide sweep is necessary to sever roots 6+ inches below the crown to turn perennial crop biomass into the soil to enhance kill and incorporation. Growers have followed the plow with a heavy disk and field cultivator to further incorporate residues and break up clods and root balls.

It is very difficult to achieve a 100% kill of alfalfa in organic operations. Several studies have found benefits of intercropping Kernza and alfalfa, so a few alfalfa volunteers should not be harmful. Larger amounts of alfalfa can cause excessive competition for moisture or nutrients. In addition, alfalfa can go to seed in a Kernza + alfalfa stand, resulting in alfalfa seed in the Kernza lot that needs to be cleaned out. From grower experience, these green alfalfa seedpods can contribute to extra moisture and heating of harvested grain. If alfalfa seeds are present, take extra care to ensure proper air flow and drying after harvest.

The following sections provide general recommendations for Kernza establishment and management but also recommendations for specific regions and production systems. Researchers are working to expand the scope of this work and updates to this guide will be made as new information becomes available.

Case study

A farmer in the Upper Midwest terminated alfalfa with a chisel plow set to 8-inch depth after 4 years of alfalfa. The decision to undertake heavy tillage between perennials represented a tradeoff between soil health management and optimizing chances of successful Kernza establishment. Even with this level of tillage, approximately 30% of the alfalfa stand regrew after 1-2 years, resulting in a Kernza-alfalfa intercropped stand.

Alfalfa provides some benefits to a Kernza stand, including some biological nitrogen input and improvement in stand forage quality if forage is harvested. However, excessive alfalfa regrowth will impede Kernza establishment and will compete for water and nutrients in an established stand. These tradeoffs need to be considered when planning pre-establishment tillage and seedbed preparation for Kernza, especially following a perennial crop like alfalfa.

Harvested Kernza from an alfalfa intercrop field in the combine bin. The brown/green spiral-shaped seeds are alfalfa seedpods, contaminants in this case. Use caution when harvesting intercropped fields and take extra care to clean the Kernza seedlots.

Field preparation

Kernza seedbed needs are similar to those of alfalfa. Kernza requires a fine textured, firm seedbed for strong germination and a uniform stand. Kernza is very sensitive to soil crusting since seedlings are often not strong enough to break through a hard crust. This can result in inconsistent or failed stands and require reseeding. If soil crusting occurs but seedlings have not yet emerged, some growers have tried breaking up the crust with a tine weeder or similar instrument and rescued their stand (this is only a successful strategy if seedlings are not near the soil surface).

For growers in humid continental regions, such as east of the Mississippi River, tilled establishment is currently the norm, especially for organic producers. Light tillage operations (e.g., light disk) that create a fine, even seedbed are recommended. Typical field preparation sequences include disking to a maximum depth of 6 inches, followed by a field cultivator, cultipacker or roller to produce a firm seedbed and break down any remaining large clods. Tillage establishment practices must take into consideration the need to reduce volunteer cereal pressure, as well as grass weeds.

With new herbicide resources (see the Weed Management section, pg 23), more and more conventional producers are adopting no-till establishment, which is the norm in the Great Plains and other semiarid regions where soil moisture needs to be conserved. Kernza has been seeded successfully using no-till practices following corn harvested for silage and small grains, as long as residues are evenly distributed and drills are able to punch through crop residue. In Kansas and other areas using no-till practices, it is important to make sure residue is spread evenly, with no windrows left in the field.

Planting date

Optimal planting date depends on the growing region and timely planting is essential for stand establishment success. Research studies and practitioner experience have identified recommended planting date cutoffs; see Table 2 for recommended planting dates for different regions.

Fall vs. Spring Planting

Kernza can be planted in the spring or late summer/early fall. Kernza requires vernalization, a period of cold temperatures, before it will produce a seed head. Temperatures of 27 to 50˚F, (with an optimal temperature of about 40), for 4 to 6 weeks can induce vernalization in Kernza. If these conditions are not met, Kernza might not develop seed heads. *This means that spring-planted Kernza will not produce grain the same year it is planted;* the first harvest will be in its second year, after experiencing a winter. Fall-planted Kernza will produce grain the following summer, enabling economic returns from grain more quickly than spring planting. Some growers are willing to plant in the spring and forego year 1 grain harvest because they want to use Kernza for forage during its first year. An important tradeoff to consider with foregoing year 1 grain harvest is the trend of Kernza yield decline. Kernza yields are maximized in years 1 and 2, and begin declining in year 3. Choosing not to harvest grain in years 1 or 2 of the stand will likely reduce the total yield potential of a stand. Consider grain vs. forage needs and returns for each type of harvest when making establishment timing decisions.

Midwest and Northeast

In high-moisture regions including the Midwest and Northeast, it is best to plant before September 15 to allow adequate growing degree days for vegetative growth prior to winter dormancy (allowing seedlings to produce at least two leaves), and time to capture adequate rainfall. Late seeding can increase the risk of stand failure. Kernza has established successfully in unseasonably warm years as late as October 1, but this may still lead to reduced yields in year 1.[2] Seeding before a minimum of 0.5 inches of precipitation will result in rapid germination and emergence.

Northern Great Plains and West

In the Northern Great Plains and Intermountain West regions, Kernza should be planted by October 1. However, lack of fall rain can hinder establishment, particularly in areas without irrigation. In semiarid regions, spring establishment is advised if:

1. Fall precipitation is insufficient for germination and winter soil water recharge
2. Fall irrigation is not available
3. Haying in year 1 is possible (spring establishment yield grain in year 1).

Under these conditions, planting should take place about the same time as spring wheat (prior to April 15 in most regions). However, high moisture is needed to obtain adequate germination. Unlike some wheat varieties, Kernza cannot be seeded deeper than 0.5 inches to contact a deeper moisture line as seed sown too deep will not emerge. If seeding must occur while the soil moisture line is still high, Kernza may require earlier establishment than other small grains. Err on the side of earlier planting to catch spring precipitation and shallower planting depths to ensure that emergence occurs.

If using irrigation, apply 0.5 to 1 inch of water within two weeks after seeding. Kernza will benefit from additional irrigation during the first 6 months. Applying 1 to 2 inches of water during the active growth stage (tillering through elongation stages) will benefit grain yields, but Kernza is very drought hardy and will usually still produce grain in areas where irrigation water is not available.

Table 2. Recommended planting date ranges for optimal Kernza establishment. Recommendations do not guarantee successful establishment but give the high success rates. Spring plantings are for forage production ONLY, as Kernza will not head out without cold exposure.

Region	States	Fall Planting	Spring Planting*
Upper Midwest	Michigan, Minnesota, Wisconsin	August 1 - September 15	Before May 30
Lower Midwest	Iowa, Illinois, Missouri, Ohio	August 1 - September 30	Before April 15
Northeast	Maryland, New York, Pennsylvania	August 1 - September 15	Before May 30
Central Great Plains	Kansas, Nebraska	September 15 - October 30	Before April 15
Northern Great Plains & Great Basin	Montana, North Dakota, South Dakota, Wyoming	By September 15 if enough moisture	Before April 15
Inland Pacific North-west	Parts of Idaho, Oregon, Washington	By September 15 if enough moisture	Before May 30

Case study 1:
Emphasizing grain production in a humid climate type

Bob Smith of Smith Grain Farms in Decorah, IA, wants to maximize Kernza grain yields and does not have a way to use forage. Bob plans for fall Kernza establishment in 2022, in order to harvest grain in August 2023.

Bob plants oats in spring 2022 to allow for early harvest and field preparation. He harvests oat grain on July 10, allowing his oats to volunteer during late July/early August. He preps the seedbed with a tandem disk + soil finisher and establishes Kernza on September 1. Bob follows the establishment recommendations in this guide and achieves a successful stand which he harvests in August 2023.

The stand produces a grain harvest averaging 450 lb/acre. Bob can expect high Kernza yields in years 1 and 2 (2023 and 2024), after which yields may begin to decline as Kernza grain yields are maximized in years 1 and 2, and begin to decline in year 3.

Case study 2:
Dual-purpose production in a humid climate type

Marci Tartt farms in southern Wisconsin and decides to grow Kernza to provide supplemental high-quality forage for her heifers. She can use the grain in her sister's bakery (her sister has a seller's license from TLI).

Marci plants Kernza in the spring to reduce her hay purchasing bill and to get more time to plan harvesting logistics. She plants in April 2022 and cuts forage twice, in June and September. She does not harvest forage in spring of 2023, allowing Kernza to grow and produce seed, and harvests her first grain crop in August 2023.

Marci grazes heifers on the post-harvest regrowth in October 2023. Marci starts to see a decline in grain yields in 2024. Note: Even if Kernza is only harvested for forage in year 1, that still counts as a high-yield-potential year. Therefore, spring establishment could potentially reduce total grain yield of the stand.

Case study 3:
Choosing optimal soil moisture conditions for good establishment in a semiarid region

Martin Hernandez in western North Dakota wants to grow Kernza for its drought hardiness and strong grain profitability potential. He has a grain buyer lined up and a small beef herd as a backup use for Kernza forage. Martin knows that soil conditions in his area usually stay dry until November, after which the ground freezes quickly. He's certain fall establishment won't be successful, and plans to plant Kernza in spring and graze his beef herd in year 1.

Martin plants on May 1, 2022, and harvests in August 2023 and harvests another successful grain crop in August 2024. In 2025, western North Dakota is hit hard with drought conditions, and Martin decides to forego harvest and graze his cattle on Kernza due to other pasture losses.

Having Kernza reduces Martin's need to purchase expensive off-farm hay and keeps him in business in a challenging year.

Row spacing

Small grains are typically grown on narrow rows (6 or 7.5 inches), and many Kernza growers choose similar row spacing. However, researchers have found that tradeoffs exist between row spacing and yield persistence of a Kernza stand. Similar to other perennial crops like alfalfa, Kernza grain yields are maximized in years 1 and 2 and tend to decline starting in year 3, and especially in year 4. Research studies have observed grain yield declines of 60% to 80% from year 1 to year 4 in stands seeded on narrow rows (6 or 7.5 inches).[3] Forage yields tend not to decline substantially in year 4 and beyond. Studies have shown that increasing row spacing to 12 inches or wider can reduce lodging, maximize straw and hay yields, and maximize grain yields over time.

Row spacing information is limited and information here is based on two studies. The first one looked at yield and row spacing after defoliation in Kernza rows spaced 6, 12 and 24 inches apart. This study showed that wider spacing

at 12 or 24 inches decreased interrow competition between plants, decreased lodging and maximized yield over the 4-year study.[4] The second study found that hay and straw yield and value were higher with row spacing at 6 or 12 inches versus 24 inches.[5] More research is ongoing to identify drivers of grain yield declines and to develop management recommendations to counter this physiological tendency.

For growers considering planting on wide rows 24 inches or greater, they may not experience significant yield declines in year 4 and beyond if weeds are properly managed. A tradeoff is that in years 1 and 2, because a smaller percentage of land area is planted to Kernza, grain yields tend to be lower in wide row spacing stands than in narrow row spacing stands.

When selecting a row spacing, decide whether to prioritize high grain yields in years 1 through 3, or longer-term yield stability. If planting wide rows, have a plan in place for weed control (if conventional, be prepared to apply the approved herbicide in spring; if organic, inter-row cultivation will likely be necessary). If weeds are not controlled in interrow spaces they will overtake the Kernza stand and yield longevity will be sacrificed.

Seeding rate

Typically, Kernza is seeded at 10 to 18 lb/acre. Seeding rates should be determined based on seed lot germination rate, management type (conventional vs. organic, where organic operations often seed at higher rates), soil conditions, and row spacing. Research trials have identified optimal seeding rates for stand vigor and yield maximization; refer to Table 3 to identify the appropriate seeding rate. Seed bag tags and seed suppliers will provide the percent germination and percent pure live seed (PLS) numbers needed to choose an optimal seeding rate.

These seeding rates are general recommendations. To reduce the risk of stand failure, which remains a large risk at this stage, consider using a higher seeding rate than appears in the table. Organic growers may want to use a higher seeding rate to increase early crop competition with weeds. The likelihood of successful stand establishment in tough soil conditions is likely to increase when using higher seed rates.

Table 3. Recommended Kernza seeding rates. Identify row spacing (left; rows) and the seed lot's germination rate (top; columns) to identify the recommended seeding rate in lb/acre. Seeding rate recommendations are generated from research conducted at UMN and TLI.

		Germination rate						
		40%	50%	60%	70%	80%	90%	100%
		Pounds of pure live seed per acre						
Row spacing (inches)	6	25	20	17	14	13	11	10
	7.5	29	16	13	11	10	9	8
	12	13	10	8	7	6	6	5
	15	10	8	7	6	5	4	4
	24	6	5	4	4	3	3	3

Seeding depth

Kernza's optimal seeding depth is 0.25 to 0.5 inches, so equipment should be set to 0.5 inches or shallower. Kernza has a shorter hypocotyl than wheat and will not be able to emerge if planted deeper than 0.5 inches. Planting seed too deep is believed to be the primary cause of establishment failure. All growers establishing Kernza should thoroughly inspect seed placement throughout the period of seeding, but especially in the first three to four passes across the field, adjusting settings to achieve the correct depth. Err on the side of shallower seeding depth–seeing 10% of seed on the surface, and 90% lightly covered with soil is likely to result in a good stand.

Equipment selection, settings, and considerations

Kernza can be seeded with a drill set to a shallow depth, a Brillion seeder, or a broadcast grass seeder. See Table 4 for more details to consider when choosing seeding equipment. When using any of the options below, check seed distribution and placement in the field during planting to ensure seeding recommendations are followed and equipment is performing as intended. Plan for the considerations listed for each seeder type carefully.

Table 4. Seeder types, brands, and important factors to consider when selecting and setting a seeder for Kernza.

Seeder Type	Brands	Considerations
Drill	John Deere, Great Plains, Truax, etc.	• Set down pressure very shallowly • Check seed placement in field BEFORE seeding entire field • Can have a tendency to seed Kernza too deep if operator is not careful • Kernza seed can "bridge" in the seed box and not flow consistently, creating an uneven stand • Best to use stirring machinery (e.g., StirAtor) in the seed box to prevent bridging and optimize seed flow down into the tubes • Can mix Kernza seed with cracked corn to prevent bridging
Brillion	Landoll, Turfmaker, etc.	• Can be difficult to calibrate–do so carefully • Requires even and firm seedbed
Broadcaster	Herd, etc.	• Likely will need to follow with a roller or tine implement to ensure good seed-to-soil contact • In some cases, seed sitting on the surface can wash away in heavy rain

Soil type notes

Soil type matters, especially if you are working with clayey soils–Kernza is not easily able to break through soil crusting. If your soil is prone to soil crusting, plant Kernza more shallowly. Certain soil types are more forgiving on seeding depth. Take your soil type into consideration when setting your seeder. Sandy soils can be planted a little deeper, whereas clay soils must be planted more shallowly. Additionally, the expected rainfall and weather patterns for your area need to be considered when planting Kernza. Some growers have had success breaking soil crusts if Kernza seedlings have not yet emerged.

Table 5. Settings used to establish Kernza at several MN sites, shown for specific drill brands

Drill	Row spacing (in)	Seeding rate (lb/acre)	Seeding rate setting	Drive speed	Grams / per 100 ft. of row	Notes
Great Plains 606 NT	7.5	10	11 (equivalent to 16 lb/acre for oats)	4	6.5	–
Great Plains 1006 NT	15	11	25	4	17	Drill set up with openers every 7.5 inches, taped closed every other meter to achieve 15 inch row spacing
JD 8300	18	5.5	14 (equivalent to 52 lb/acre for oats)	6	9	Drill set up with openers every 6 inches, taped closed every two meters so every third row was seeded
JD 1560 NT	15	11	35	–	14	Only used rear openers, to achieve 15 inch spacing
Truax Flex II 88	24	6.5	3 on box dial	–	14	Seeded through grain box; used agitators
Crust Buster All Plant 4615	15	13.5	–	–	13	Seeded using the legume box

No-till notes

No-till drill performance is very important for achieving consistent establishment of Kernza. The drill needs to maintain consistent downward pressure, seed placement, and depth to seed a strong and uniform stand. Ensure your drill is fully cleaned out (including carefully vacuuming out the seed cups) prior to planting, especially of small-seeded crops (such as camelina) that could become weedy in an establishing Kernza stand. The down pressure and seeding depth will likely change depending on the residue level of each field. It is a challenge for no-till growers to seed Kernza because of the need for shallow seeding and even depth throughout the field (anecdotally, 10% of seed ends up on the surface when finished planting.) Aim for .25 inch seeding depth, and know you can seed up to .5 inch to obtain good germination.

Seeder calibration

Take time to seed Kernza correctly. Currently, the biggest problem with Kernza production is establishment failure. If Kernza is seeded too deep (>0.5 inch) and at too low a seeding rate, establishment failure and disillusionment are likely. Stand establishment requires calibrating the seeder and testing the settings for accuracy. Drill/seeder calibration matters a lot with Kernza; use an accurate scale. There is a wealth of seeder calibration information and videos on the web.

Checking seeding rates is essential for successful establishment

Drill calibration tips: Disconnect the seed tubes from the openers and fasten small plastic bags to the tubes with rubber bands. Drive the drill 100 ft. Separately weigh the seed that is deposited into each bag, using a battery operated kitchen scale. Note the variability and adjust seeding rates accordingly.

Seed bridging in drills and seed flow

Seed "bridging" in the seed boxes on drills is a potential contributor to establishment failure. Because Kernza seed has a hull, seed lots are "fluffier" than typical crop seeds for which seed boxes were designed. This can impede normal downward flow of the seeds in the seed box, through the feeding system and into the tubes to the feet of the drill. When this "bridging" occurs, large gaps will be evident in the stand when the Kernza emerges–in some cases, entire rows will be missing in multiple passes. These gaps allow weeds to establish and proliferate, and growers often decide to terminate and reestablish the stand at large cost. To prevent this, growers have mixed Kernza seed with rice or other dense seed (e.g., cracked corn) to aid in flow through drill mechanisms, or have had someone ride on the back of the drill during planting to mix and push the seed downward in the seed box. Growers should be proactive about preventing bridging, *which has been observed in almost all brands/models of drills*, and check frequently while planting to ensure that target seed populations are being distributed.

Evaluating establishment

Depending on soil moisture and temperature, Kernza seedlings will begin to emerge approximately 10 to 20 days after sowing. Stands can be evaluated for establishment success by counting plants within planted rows. Wait at least 14 days after seedling emergence to conduct plant counts to ensure that most seeds have germinated. Plant counts should be taken at multiple locations within the field, including areas with both good establishment and poor establishment. On average, stands with 5 to 6 plants per foot are considered well established. Stands with 3 or fewer plants per foot will likely be too thin to be viable, but Kernza can fill in space via tillering and other propagation methods. Depending on the other crops available to a farmer in a rotation, it is recommended to wait till the following spring to decide whether termination is necessary or not. In many cases, even a thin stand will "fill in" by the end of year 1, leaving the farmer with a competitive, viable stand for subsequent years without having to incur the cost of terminating and reestablishing.

A successful Kernza seeding. Plants were seeded on September 7 and photographed on October 10. Stands counts in this field averaged 5.6 plants per foot.

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CHAPTER 3: Nutrient, Weed, and Disease Management

"The best fertilizer for a piece of land is the footprints of its owner."
– Lyndon B. Johnson

"Damn thistles."
– Anonymous

Nutrient management

Nutrient uptake and temporal and seasonal dynamics differ significantly in Kernza compared to annual small grains. Several studies show that IWG decreases nitrate leaching by 77% to 99% compared to annual grains. Calculating nutrient application rates based only on removal rates (measuring nutrient content of exported grain, straw, and other products) will likely lead to nutrient insufficiency in the short and long term because Kernza's root biomass increases over the life of the stand and nutrients may be tied up in an increasing microbial pool. There is also some evidence that while perennial crops have higher total system nitrogen, a larger proportion of that nitrogen exists in organic, non-plant-available forms. For example, soils from an alfalfa-based system may contain 4% total nitrogen but only 5% of that nitrogen is in ammonium or nitrate form, compared to an annual corn system where soils contain 3% total nitrogen but 20% of that nitrogen is ammonium or nitrate. Nutrient application needs may change over the life of a Kernza stand and with new varieties released, since grain exports increase with improved yields. *For the current varieties available, and of the field trials conducted thus far, 70 to 90 lb N/acre is the recommended annual N application rate for years 1 through 3 of Kernza production.*

Nitrogen Rate: What We Know

Field studies conducted at five sites in Minnesota across three years of Kernza production observed that grain yields were maximized at 80 lb N/acre and tended to decrease with higher rates, often due to increased lodging (Jungers et al. 2017). Decreasing grain yields at higher N rates was observed to the same extent in year 3 as in years 1 and 2. The reason for this trend is unknown but may be due to lower overall yield potential and response to nitrogen fertilizer of the stand, and/or to high rates of microbial N immobilization in the soil. There is some concern about increasing rates of N tie-up, immobilization, and decreased

plant availability in later years of the stand, possibly contributing to the lower yields in 4+-year-old stands. In analogous tallgrass prairie systems, plant-available (soluble) N levels in the soil are very low, often <5 ppm, because of the highly resource-competitive environment. Given that Kernza systems have many similarities to native grass systems, low N availability might contribute to lower grain yields after 3 to 4 years. Knowledge around these dynamics and how to manage them is limited.

The current recommendation is to test soil annually for, at the minimum, ammonium and nitrate levels, and to use these values in nutrient management and fertilization plans. Keep in mind that soil ammonium and nitrate levels are constantly in flux. Levels from one soil test should be viewed as a general guide only, rather than as an absolute number in the way we view phosphorus or potassium levels, which experience less flux. In general, soil test ammonium and nitrate values of <10 ppm are very low for grain crop production, and indicate a possible need for fertilizer amendments. As Kernza grain yield potential declines in year 3 and beyond, additional fertilizer application is unlikely to increase productivity and economic returns. As research and on-farm experimentation continue to uncover strategies for sustaining productive stands beyond three years, this recommendation may change. Stay tuned for updates on increasing stand longevity.

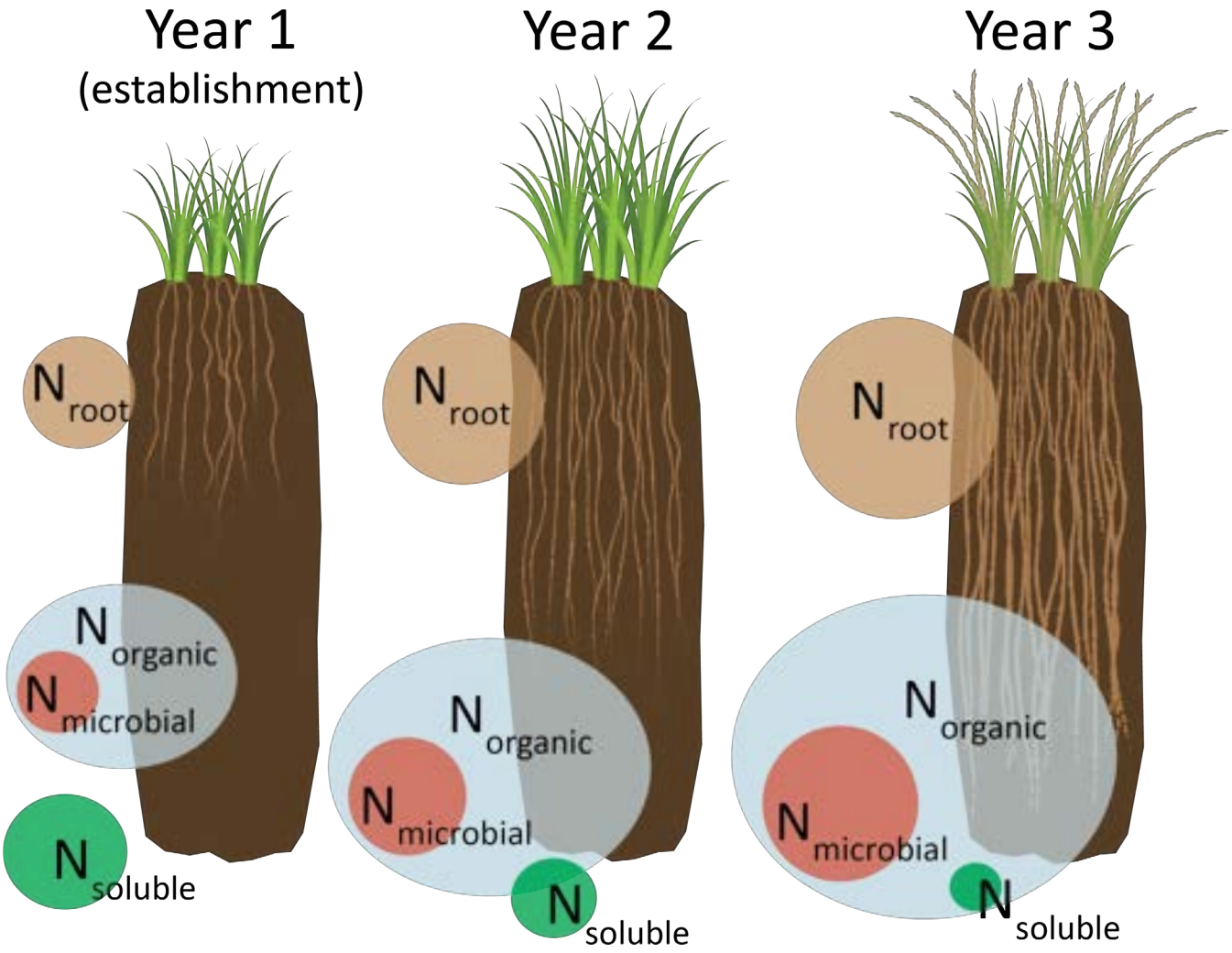

Figure 1. Depiction of the changing size of nitrogen (N) pools across years 1 to 3 of Kernza production. Production year means a year in which you harvest grain.

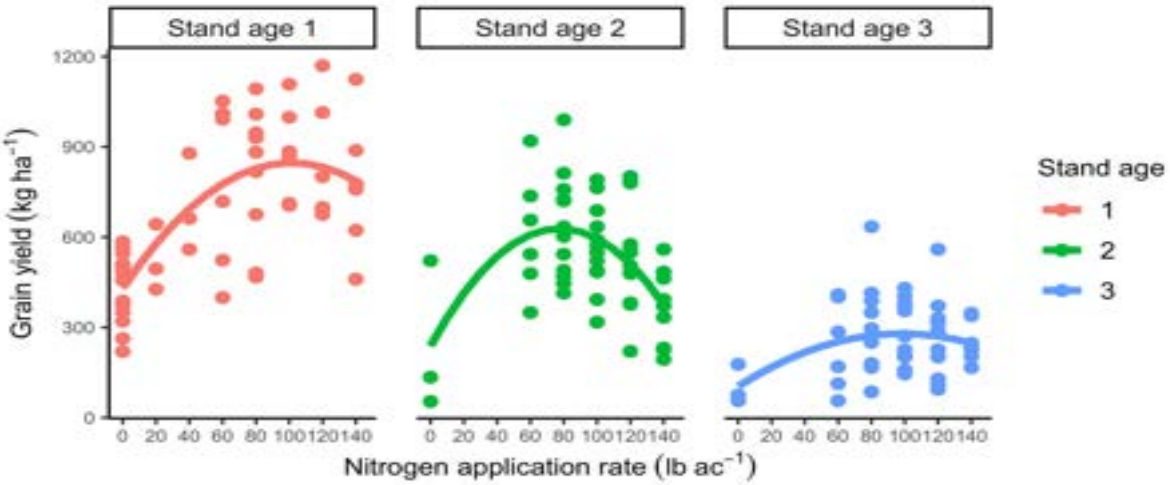

Figure 2. Kernza grain yield responses to a N fertilizer series (0, 20, 40, 60, 80, 100, 120, 140 lb N/acre) applied as surface broadcast urea. Christensen et al., in prep, figure: Jacob Jungers.

N-Application Timing

For conventional production, it is typical to fertilize in spring at "green-up," just before the active tillering phase. However, many organic growers find fall application of manure to be beneficial for grain yields and *fall manure application is recommended for Kernza* (most growers apply 1 to 3 tons/acre poultry or other livestock manure via surface broadcast). Fall application of manure or other organic amendments allows time for mineralization and greater N and other nutrient release. Spring application does now allow adequate nutrient availability for Kernza. Additionally, applying in the fall generally risks less soil compaction than applying in the spring. In semiarid regions, even less nutrient release is expected if spring spreading is employed because hot and dry conditions usually come early in the year, limiting mineralization rates until moisture arrives again in the fall. Historically there have been concerns about applying manure in the fall for leaching and nutrient export potential. Since Kernza has living roots in the soil year-round, there is less concern about fall application resulting in nutrient pollution. In summary, fall application is recommended for organic amendments.

Research into optimizing timing of conventional fertilizer application is ongoing. Some preliminary results suggest that split applications (50% applied in fall, and 50% applied in spring at the "green-up" stage) result in optimal yields, but more study and analysis is needed. Updated fertilizer timing recommendations should be available in two years as current studies conclude.

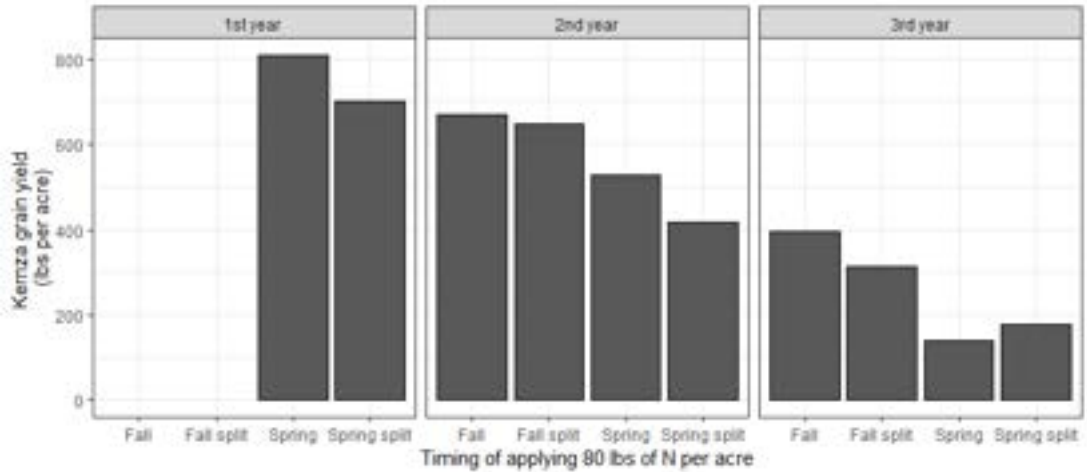

Figure 3. Kernza grain yield response to N fertilizer application timings. N fertilizer applied at a total seasonal rate of 80 lb N/acre. Split applications received 60 lb N/acre in fall or spring, and an additional 20 lb N/acre in the summer. Figure credit: Jesse Puka-Beals.

P, K, S Rates: What We Know

Little is known about optimal P, K, and S rates, although coordinated field trials are currently underway to assess Kernza grain yield response to applied P, K, and S. This guide will be updated as results are available. At this time, it is recommended that Kernza producers submit soil samples for routine fertility analysis prior to planting and add amendments to maintain P, K, and S levels similar to those recommended for annual wheat. The following soil test levels of P and K are recommended for Kernza production: at least 21 ppm Bray-P (16 ppm Olsen-P), and at least 121 ppm K. Sulfur application is increasingly common among small grain producers, although yield response is unclear. Sulfur fertilization is generally recommended for producers growing on sandy soils at an annual application rate of 10 to 25 lb S/acre. Sample soils and submit them for testing early enough to apply and incorporate fertilizers prior to planting. Topdressing established Kernza to increase soil P, K, and S may not be as effective as incorporating fertilizers prior to planting.

Weed management

Weed management must be approached diligently in Kernza, like any other cash crop. However, Kernza's perenniality makes it uniquely competitive after it is established and it is potentially a useful rotational crop for mitigating pressure from certain summer annual weed species (for example, lambsquarters, ragweeds, and pigweeds in the Midwest) in years 1 to 3 of the stand. However, as stands age (>4 years), weed pressure can increase again and require management.

Weed control measures in Kernza are most important *in the year of establishment.* Volunteer plants or other weeds germinating in fall can inhibit Kernza emergence and seedling growth, and winter annual-type weeds like shepherd's-purse and pennycress (Midwest) and winter annual grasses like downy brome, cheat, wild oat, and jointed goatgrass (Great Plains, Great Basin, Pacific Northwest) can canopy early in the spring following establishment and smother out the young Kernza plants. *If not controlled, these weed issues will cause considerable stand losses.* Although

Managing volunteering plants in the establishment year

This guide has covered tradeoffs of different rotational crops one can employ prior to Kernza, and recommends spring-planted grain or legume crops as ideal choices, followed by alfalfa (remember that winter crops like winter wheat and rye are to be avoided at all costs as they will not winterkill and will contaminate Kernza fields and subsequent grain lots). Even in cases of ideal rotational crops like spring oats, volunteer plants in fall are likely and have been observed to inhibit Kernza stand establishment.

Whether conventional or organic, we recommend allowing time for volunteer plants to germinate prior to initiating Kernza establishment seedbed prep. Once you see a flush of volunteer plants, ideally in late August or September following a rain, initiate control measures (light tillage for organic, and burndown herbicide for conventional). If you are relying on irrigation to initiate Kernza germination in the fall, consider applying a small amount of irrigation water to germinate volunteers prior to planting Kernza. Using this "stale seedbed" technique will allow you to deplete a significant amount of the volunteer seedbank and decrease pressure on your newly germinated Kernza.

Planting after organic alfalfa. Alfalfa is difficult to terminate completely in organic situations, and you will likely see some alfalfa "volunteering" (or rather, regrowing from root pieces) in Kernza in year 1 and beyond. Regrowing alfalfa is unlikely to cause establishment issues unless termination tillage was insufficiently aggressive; however, it can regrow significantly as the stand ages. Mowing alfalfa patches very early in the spring and late in the fall right before fall dormancy can stress alfalfa plants and lead to declines in alfalfa vigor that favor Kernza growth and competition. On the bright side, a few alfalfa plants sticking around can create stand diversity and input biological nitrogen to the system, so "volunteering" alfalfa is not always a bad thing!

weed management differs between organic and conventional systems, both systems work best in fields where weeds are under control. As one researcher says, "Kernza is not a magical crop that will grow anywhere." The below sections include recommendations for both conventional and organic systems.

In the Great Plains, Great Basin, and Pacific Northwest regions, growers should watch out for Russian thistle, which can inhibit stand establishment and vigor if present in high numbers. Some suppression of Russian thistle has been observed in year 2 once Kernza was established; however, large patches of Russian thistle should be approached with caution and control measures should be taken.

Established Kernza's ability to compete with common troublesome perennial weeds like Canada thistle and field bindweed is under debate; some growers have observed significant suppression of these species, while other growers have experienced Kernza stand losses from thistle patch growth, similar to what one expects with annual crops. More research in this area is needed. In the meantime, planting Kernza into areas infested with these perennial weed species is not recommended.

Conventional weed control

A 2,4-D amine herbicide, Nufarm's Weedar 64, is now approved for use in IWG/Kernza. At this time, only Weedar 64 from Nufarm has IWG on-label; other 2,4-D products do not. Several other 2,4-D products and other herbicides are in the approval process, but until they are listed on-label, they are not approved for IWG/Kernza grain production.

The use of Weedar 64 (2,4-D amine) in Kernza is more restricted than in other grain crops. Only a single application per season can be made on Kernza destined for grain production, and that application can be made only in spring. Weedar 64 cannot be applied in summer, autumn, or winter. Spring applications can be made only after Kernza seedlings have tillered (4 to 8 inches tall), but before the boot stage of growth. Do not apply Weedar 64 before or after these developmental stages.

Follow the label to adhere to lawful standards and to identify the maximum rate per season of active ingredient, as well as other application guidelines. Lower rates can be used if weeds are small (e.g., cotyledon stage); however, rates lower than 0.5 pint/acre (0.25 lb ae/acre) are not recommended unless legumes are underseeded purposefully into the Kernza stand.

Curtail-M(R) is a mix of clopyralid and MCPA and has been approved for use on Kernza. This post-emergence herbicide controls broadleaf weeds and can be especially effective for killing species of thistle. Application to Kernza is restricted to the spring, after plants have reached the three-leaf stage but before plants reach the boot stage. Follow the product label closely to determine application rates.

No-till farmers have few options for in-crop weed suppression at this time, although there are several IR-4 applications underway to expand herbicide options for IWG for grain production. CAUTION: there are several herbicides labeled for IWG for pasture, CPR mix, and/or forage/fodder systems, *but that does not mean that these herbicides can be used in Kernza and for grain production.* Wait for guidance from The Land Institute and other Kernza technical providers before applying herbicides other than Weedar 64 and Curtail-M on Kernza for grain production. At this time, only burndown herbicide applications are allowed prior to seeding, but be sure to follow the label. Conventional growers are encouraged to follow the strategies recommended below for organic growers until more herbicide options become available, and even then are encouraged to practice integrated weed management strategies.

Organic weed control

For organic growers, tillage is key prior to establishment. Tillage does not need to be deep or intensive, but should be sufficient to create a clean seedbed where weedy plants are terminated and incorporated to encourage breakdown. Chisel plows and disks are good tillage tools to prepare for Kernza establishment. Post emergence, tine weeders and rotary hoes can be utilized once Kernza seedlings are firmly rooted. Tine weeders

and rotary hoes run across the ground at high speeds can uproot and control small germinating broadleaf weeds and some grasses prior to Kernza canopying. If a grower chooses to plant wide rows (24 inches or greater), interrow cultivation may be possible to manage weeds between rows.

It is common to experience high winter annual weed pressure in the spring following establishment. In this case, weeds often grow faster and form a canopy above the small Kernza plants. If this occurs, mowing over the top of the Kernza canopy can allow light to penetrate through to the young Kernza plants. Set the mower deck so it just clips the tops of the Kernza leaves, mostly catching the above weed canopy. Be careful to not mow too much of the Kernza plant to prevent damaging the young "primordium," or developing seedhead inside the stem, which would result in a lower number of reproductive grain spikes and lower yields. Inspect the Kernza growth stage prior to mowing and be careful to set and maintain proper mower deck height. Often, just one round of mowing can give the Kernza enough light and time to outcompete weeds in year 1 and form a competitive stand and strong canopy. This mowing approach will likely only be necessary in year 1, but may become necessary again as stands age and become less vigorous (year 4+).

Kernza primordium, the developing seedhead. Damage to this seedhead embryo will result in grain yield loss.

No-till organic establishment is not recommended at this time, given the difficulty experienced with establishment. *Do not no-till Kernza into a weedy or preexisting grassy field under any circumstances.* This will lead to failure and wasted money purchasing Kernza seed. Successful strategies for this approach may be developed in the future.

Disease concerns

Kernza currently faces few major disease problems. The most important concerns are *Fusarium* root and crown rots, *Fusarium* head blight, and ergot.

The *Fusarium* complex is caused by a widespread fungus that can be transmitted via wind or infected soil and seed. Plants infected with *Fusarium* have brown, dying tissue at the base of the plant, and roots will not develop properly (shortened roots with brown tissue on the root tips will sometimes be visible). If infected plants progress to heading, *Fusarium* head blight will cause brown/white spikelets, which may have underdeveloped grain, or may be empty of grain.

All grass crops are susceptible to the *Fusarium* complex, so diverse rotations are the most effective way to prevent it. Include broadleaf crops in rotation and avoid planting Kernza immediately after grass crops such as corn, winter wheat, or sorghum. Control grass weeds both within and around the field, including keeping fencelines and hedgerows well mowed. Many growers want to plant Kernza after spring small grain crops such as oats to ensure timely Kernza seeding in a rotation. It may not result in *Fusarium* infection, but it is a risk that growers should take into account.

Fusarium infection risk is closely related to precipitation during flowering and excess moisture during seed development. So, while inoculum are almost always present in widespread hosts like corn stubble, infection doesn't always occur. Thus, Kernza fields with *Fusarium* problems in one year might not necessarily have *Fusarium* problems in following years.

Fusarium head blight can cause high levels of deoxynivalenol (DON, also known as vomitoxin), which is toxic to humans and livestock. Every lot

of food or feed grade Kernza must be lab tested for DON. The FDA limit for DON levels in food-grade grain products is 1 ppm, and grain with more than 1 ppm cannot be sold for food. Grain with up to 10 ppm DON can be used as livestock feed. (FDA guidelines for total DON concentration vary by type of animal.)

Kernza must also be tested for aflatoxins B1, B2, G1, and G2, a type of toxin produced by *Aspergillus* fungi species. The FDA limit for aflatoxin in food grade grain is 20 ppb, but up to 300 ppb is permitted in feed grain.
Aspergillus species can infect many crops before or after harvest, especially in hot and humid conditions. To prevent aflatoxin levels from exceeding thresholds, follow the cultural controls described above, and ensure that grain stays dry (<14% moisture) during post-harvest storage.
A grain sample can be sent to an analytical lab for vomitoxin/DON and aflatoxin tests. (Dairyland Laboratories, Inc. is accustomed to analyzing Kernza grain quality and has locations throughout the northern US. See www.dairylandlabs.com/ for more information.) When submitting samples to an analytical lab, request all of these tests to ensure that the grain meets food and feed specifications. Note that the FDA limits are for finished products intended for consumption, such as flour. Some studies have found that the hull contains the majority of vomitoxin and aflatoxin content. Farmers should consider sending dehulled grain for testing, which will usually have lower vomitoxin and aflatoxin levels than unhulled grain.

Ergot is caused by the fungus *Claviceps purpurea*. It can infect all cereal crops, but rye and ryegrasses are particularly vulnerable. The fungus overwinters in the soil and generally releases infectious spores during the summer season, coinciding with pollination. Wet, cool, and cloudy conditions favor ergot infection. In infected spikelets, a fungal sclerotium grows in place of the grain.

Ergot sclerotia contain psychoactive alkaloids that are toxic and potentially fatal to humans and livestock. Ergot limits are based on sclerotia weight per grain weight and vary from 0.05% in wheat to 0.3% in rye. To measure ergot content, take a representative sample of 1,000 kernels of grain and count the number of ergoty grains. Weigh the Kernza grain and ergot grain fractions and

Fusarium mycelium on a piece of Kernza residue

calculate the ergot percentage of your seed lot. Talk with your buyer to understand their ergot limits and to decide what level of cleaning is necessary. Ergot sclerotia are dark purple to black in color and generally longer than the grain, making it possible to clean out in small amounts by size or by color sorting. Some grain is usually lost during color sorting as well, reducing marketable grain yields. Re-testing is required after cleaning to ensure that enough ergot was removed.

The best way to prevent ergot is through timely harvest of Kernza grain, and by following crop rotation practices recommended above for *Fusarium*, such as alternating broadleaf crops with grasses in a multi-year rotation.

Other diseases have been observed in Kernza but have not been found to result in significant yield losses or stand longevity. Some of these include: Bacterial Leaf Spot, Spot Blotch, Tan Spot, and Brome Mosaic Virus.

Fusarium infection on a Kernza spike (at the base of a floret)

An ergot fruiting body near the top of a Kernza spike. These ergot bodies will thresh off at harvest and will need to be cleaned from grain lots

Pests

Very little is known about pests in Kernza; few pests have been observed that caused stand loss in the main production areas (Upper Midwest, Kansas, and Montana). In the Midwest, the main pest to look for is fall armyworm (*Spodoptera frugiperda*), which in the larval stage is a widespread pest of many grass crops. Fall armyworm can move into and through a grass field very quickly, starting feeding on leaf tissue at the grass margins and until they defoliate the majority of leaves and the whorl. Fall armyworm larvae, in sufficient numbers, can raze an entire grass field if not controlled. Outbreaks can occur from the end of June through September. Scouting is necessary, especially if armyworm outbreaks are reported by others in the area. Many conventional pesticides are labeled for fall armyworm, but need to be registered/labeled for allowable use in Kernza stands for grain production. Organically, Bt-based sprays are highly effective on fall armyworm if sprayed early in an outbreak.

In the Great Plains, wheat stem sawfly (*Cephus cinctus*) may impact Kernza stands since IWG has been shown to be a host.[1] Wheat stem sawfly is an important pest of winter and spring wheat, causing up to 20% yield losses. Larvae feed on grass stems and if not controlled, eventually cut stems at the base, causing lodging. Reports of wheat stem sawfly in Kernza are anecdotal at this point and formal studies have not been conducted. Still, growers, especially in the West or Great Plains, should be aware of and lookout for wheat stem sawfly in Kernza stands. It is commonly observed in May and June, starting when field temperatures are above 50˚ F. Inspect plants for larval presence by cutting open the stem all the way down to the base of the plant–a single larvae will be found within each stem. Larval damage can occur prior to grain harvest, and may affect fall regrowth as well. Colorado State University Extension offers resources on wheat stem sawfly here: https://extension.colostate.edu/topic-areas/insects/wheat-stem-sawfly-a-new-pest-of-colorado-wheat-5-612/.

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CHAPTER 4: Kernza® for Dual Use: Grazing and Haying

"Throughout the history of … grasslands, large herbivores were abundant and conspicuous components of the biota."

– Alan K. Knapp et al., 1999

As a perennial, Kernza can provide additional value from fall regrowth via hay/forage cutting or grazing. Due to Kernza's relatively low grain yields, producers are encouraged to manage for both grain and fall forage to bolster agronomic and economic returns. Kernza also produces straw, typically more than annual grains, that is available after grain harvest. Straw can be used like that of other small grains, but is more versatile since it contains more protein and nutrients. The following chapter contains information on biomass production, forage quality, utilization potential, and grazing management when using Kernza in an integrated crop-livestock operation.

Summer straw

Unlike small grains where straw removal is not always desirable due to nutrient and carbon export and low economic return, experts recommend removing at least some Kernza straw to promote uniform fall regrowth and enhance overall plant productivity. Forage removal, in the presence of sufficient fertility management, appears to have no impact on overall stand productivity and in some cases enhances stand longevity. Integrating forage harvest or livestock production with Kernza likely provides greater economic returns compared to grain-only systems.

Summer straw yields can be highly variable depending on the weather, location, soil, and stand age. See Table 6 for straw yield values to expect. Straw is typically cut, windrowed, and baled after harvest if direct combining, or can be baled after swathing. Some experienced growers recommend NOT swathing if planning to utilize the straw for bedding or fodder, as swathing chops the straw too much. Leaving a stubble height of <4 inches is recommended with straw removal. See *Chapter 5, Harvesting* for more information.

In terms of feed value, Kernza straw at harvest is generally similar to or slightly than other small grains like wheat and rye, with reported relative feed values (RFV) of 70 to 80.[1] Kernza straw has NDF ~70%, ADF ~43%, and crude protein ~5%. Intercropping Kernza with red clover can enhance the crude protein of the summer forage up to three fold (CP ~15%).[2]

Table 6. Kernza summer straw yields reported in published research studies.

Study	Location	Summer Straw Biomass Yields (ton DM/acre)
Pugliese et al. (2019)[3]	Ohio	1.7 - 4.0
Picasso et al. (2019)[4]	Minnesota	2.2 - 5.8
Olugbenle et al. (2021)[5]	Wisconsin	1.0 - 2.5
Law et al. (2021)[6]	New York	1.7 - 3.5
Mårtensson et al. (2021)[7]	Sweden	1.7 - 3.6

Fall forage (after grain harvest)

Kernza regrowth begins after harvest, generally as soon as the plant receives enough moisture to initiate regrowth. In regions with regular summer rainfall, growers can expect regrowth to begin as soon as two weeks after straw cutting is completed. In semiarid regions, regrowth may not begin until at least 0.5 inch of fall rainfall occurs (as late as October in some areas). In many regions and years, fall forage production is sufficient to make forage harvesting economical, and represents important additional revenue. Studies have found that fall hay yields in the Upper Midwest can range from 0.6 to 1.3 ton DM/acre.[8] Generally fall hay cutting can be performed to stubble heights of four inches or less without damaging stand vigor. Fall forage relative feed value ranged from 100 to 110 in a Minnesota study, with crude protein in the 10% to 13% range, meaning fall Kernza forage can serve as high-quality forage for beef cattle and dairy heifers.

Thus far, fall forage has only been harvested via traditional haying methods (swathing, windrowing, baling) or grazing (see below). Other methods of forage preservation have not been examined by many growers or researchers. Grazing is the most popular dual-use management technique following Kernza grain harvest.

Cutting forage only (forgoing grain harvest)

It is recommended that farmers only grow Kernza if they plan to harvest grain. However, grain harvest may not be desired in some cases due to lack of a market or an economic preference for forage, such as during dry years where the forage may be more valuable than grain. In addition, while harvesting Kernza grain may not be economically viable in stands five years or older, it can be kept in production for forage.

A recent study in Minnesota found that Kernza stands harvested in the third year can provide forage comparable to common cool season perennial forage grasses. The study evaluated cutting schedule effects on Kernza forage yield and feed value. Both first cut and cumulative annual forage dry matter yields on a three-cut schedule were maximized when cutting at the anthesis or soft dough stages (no large differences were observed between the anthesis and soft dough cutting timings). However, relative feed value of the forage was maximized by cutting at the boot stage (RFV=113), and decreased with plant maturity (RFV=80 to 90 for cuts at anthesis or soft dough).

In cases of poor stand establishment, forage harvest also provides a way to utilize first-year biomass, with the added benefit of controlling weeds through cutting.

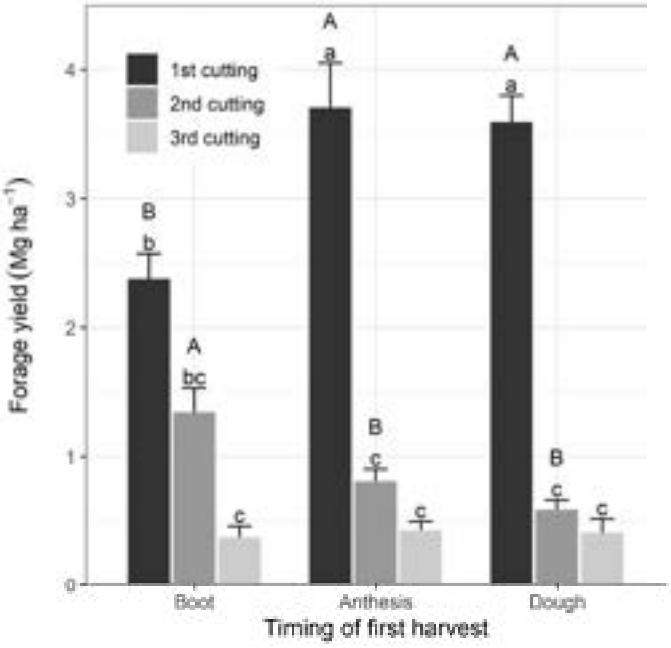

Figure 4. Kernza forage yields (Puka-Beals et al. 2022)

Kernza at anthesis (pollen shed) stage

Fall grazing

Fully established Kernza stands can be grazed in the fall. Research has found that even intensive fall grazing of post-harvest green regrowth and harvest residue does not harm winter survival or grain yields the following year, and in some cases benefits subsequent grain yields.

Research also shows good weight gain in cattle grazed on Kernza. Producers in Kansas intensively grazed beef cattle from September to March (155 days), and observed a 2 lb/day weight gain, indicating excellent forage production and quality. Kernza-alfalfa mixtures can also provide fall forage quality equivalent to a traditional grass-legume pasture. In Minnesota and Wisconsin, dairy heifers were grazed on Kernza straw stubble and fall regrowth (grown with alfalfa to supplement forage quality) from mid-October to mid-November, with average weight gains of 1.3 lb/day.

The following equation from Undersander et al. (2002) can be used to estimate stocking rates for fall Kernza fields:

Number of animals = [total acreage x forage yield (lb DM/acre)] / [0.04 x animal wt x total days grazed]

For example, grazing beef cows:

[20 acres x 1200 lb Kernza DM/acre] / [0.04 x 1000 lb x 30 days] = 20 beef cows

The following equation can be used to calculate the number of days a herd can be kept on a Kernza field:

Days grazed = [total acreage x forage yield (lb DM/acre)] / [0.04 x animal wt x number animals]

For example:

[20 acres x 1200 lb Kernza DM/acre] / [0.04 x 1000 lb x 20 beef cows] = 30 days on Kernza field

Spring grazing

Some studies, mostly conducted in the Upper Midwest, have measured spring forage and grazing potential prior to Kernza grain harvest. Any spring forage utilization must be conducted in the mid-tillering phase prior to stem elongation, otherwise one risks damaging the developing grain head forming at the base of tiller sheaths. Spring forage production is generally modest (0.4 to 1.1 ton/acre), but can have very high forage quality (RFV of 145 to 160; crude protein 20% to 28%). Spring grazing results are mixed. One study observed that grain yields were up to 50% lower on spring grazed Kernza compared to stands with no spring interventions. The detrimental effect on grain yields from spring grazing was likely due to 1) cattle trampling or eating developing grain heads (primordia) at the base of the plant, and 2) opening up the crop canopy early in the season, creating niches for summer annual weed growth and competition. Another on-farm study in MInnesota found that annual spring grazing increased grain yields in year 3 compared to non-grazed stands.

Stocking rates and grazing timing are likely important for determining impacts of grazing on grain yields, though these dynamics are not well understood at this time. Early spring grazing and early cattle removal likely risks less damage to developing seed heads and allows stands to recover in time to compete with summer annual weeds in June.

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CHAPTER 5: Harvesting and Storing Kernza® Grain

"In seed time learn, in harvest teach, in winter enjoy."
– William Blake

"Have a plan, and a fan."
– Brandon Schlautman

Identifying ripe Kernza® and harvest timing

Kernza ripens from the top of the seed head down. Ripe seed heads should be about 7" to 8" long. Note that the top can be ripe while the bottom is still green, and by the time the bottom is ready to harvest, the top can shatter. Breeders are selecting for uniform grain ripening, but until new varieties are released with improved uniformity, it is something to note. Adjust harvest times accordingly.

Seed heads tend to arch over when ready or close to ready for harvest. Harvest Kernza when you first start to observe Kernza seeds on the ground, or if you can manually shake the plant and observe spikelets fall off. Pinch a threshed kernel between your fingernails–the grain should snap, not bend. Look at multiple heads and different spikelets along the head; the majority should feel hard. You may choose to harvest earlier if you observe fungal growth on the heads to get the grain out of the field and to stop fungal contamination and infection.

Shattered Kernza grain on soil surface. Harvest should occur before this level of shattering occurs

Harvest methods

Depending on the growing region, access to equipment, and preferences, there are different ways to effectively harvest Kernza.

Table 7. Pros and cons of different harvesting methods

Harvest Method	Pros	Cons
Swathing	• Allows for earlier cutting without waiting for uniform drydown • Can result in a higher percentage of Kernza grains harvested at proper moisture for storage • Enables grain harvest in fields with large green weed infestations without plugging of combine	• Swathers not commonly owned or available in many areas • Timing can be difficult as windrows need to dry for at least 3 days in the field prior to pickup with combine; any rain on windrows likely to increase risk of mold and fungal growth • Extra pass (time and fuel) across the field
Direct cutting with standard combine draper header	• Requires only one pass across the field at harvest time • Can be achieved with standard small grain combine and header (draper type) • Good settings and adjustment can result in a relatively clean grain lot in the bin	• Plugging of combine can occur if harvesting when too much green material is present in the field • Shattering losses can be higher with direct cutting than swathing • Depending on settings used, the condition and cleanliness of grain in a combine bin can vary greatly • Can result in higher levels of green stems going through the combine, which can contribute to a “dirtier” product and can raise grain moisture levels going into storage
Direct cutting with stripper header	• Strips grain directly off seedhead, resulting in less straw and green material traveling through combine and a cleaner product in the bin • Leaves more straw in the field for straw harvest and use/sale	• Not commonly owned in many regions and not readily available to many growers; acquisition can be expensive

Combine picking up swathed Kernza

Pre-harvest sprouting can occur if swathed fields receive precipitation between the time of cutting and combining. This Kernza seed head was in a windrow for over 5 days during which temperatures remained low and periodic rain events occurred. Pre-harvest sprouting like this will result in severe reductions in grain quality

Drying Kernza spike, close to harvest time. Note the arching of the spike

Swathing Recommendations

Before swathing, make sure there will be at least one week of dry, ideally warm, weather. In humid climates, particularly in the Upper Midwest, swathing is often practiced to help green stems dry down and to allow immature grains on the grain spike to ripen uniformly. Warning: first year stands can have more variation in maturity dates, so be sure to inspect field variability in these cases. Expect improvement in uniformity in subsequent years.

In regions where swathing is a common harvest method, growers start swathing when grain moisture reaches approximately 30%. Windrows are picked up 5 to 7 days after swathing, when grain has typically reached about 15% moisture. Research studies have also obtained good results when using these grain moisture benchmarks to conduct harvest operations.[1] Dry seeds should thresh out of the spike easily and seeds should feel hard when squeezed between fingers. Remember that grains towards the bottom of the spike will not be fully ripe. Swathing should be performed when Kernza seeds start shattering off of ripe spikes; you should be able to see a few seeds on the ground. Ensure that you swath Kernza before a large number of seeds shatter from spikes, as the seed that shatters will not be harvestable with a combine once on the ground. Shattered seed can also germinate and grow in subsequent years and lead to an overly dense stand, which can reduce grain yields.

When swathing, cut at a height of 18 inches, leaving the Kernza windrow to sit on top of 18 inch stubble. Any lower and the windrow may be too close to the ground, resulting in possible fungal contamination and insufficient drying. Any higher, and the windrow is susceptible to falling into the stubble, making it difficult to pick up with a pickup header. A common mistake when swathing is using the wrong header. Do not use a disc mower, cross auger, or crimper, as they knock too much seed out of the spike and onto the ground. A draper header is required to lay grain in windrows.
Additionally, when swathing, consider the volume or capacity of the combine in advance. If using a small combine, picking up a windrow cut by an 18 foot swather may result in too high a volume of material fed through the combine, leading to plugging or insufficient threshing and cleaning. In this case, it is best to only pick up half to three-quarters the width of the swather per combine pass. Adjusting swather cutting width may be necessary from the outset, depending on the density of the stand (for example, thinner stands can include a larger width in the windrow, and vice-versa).
Windrows should dry on top of the stubble for a minimum of 2 to 3 days and up to 1 week. Do not allow rain to fall on windrows. Moisture in the windrows can cause mold and other fungal contamination that harm grain quality and can imperil the ability to meet food-grade standards. Small grain combines such as International 1440, John Deere 9000 series, etc., and small grain concaves work well for harvesting Kernza (same concaves as are used for wheat).

Sometimes the need to swath outweighs other factors, but if you want to cut, bale, and utilize straw, it is recommended that you harvest seed via direct combining and raise the header as high as possible. Then, swath and windrow the standing straw. Some have observed that swathers grind up the straw material too much, reducing straw yields and quality.

Direct Cutting/Combining Recommendations

Direct combining Kernza involves the same approach as for most small grains. One characteristic that makes Kernza unique from other small grains is the persistence of a green stem even after the seedhead has matured. Therefore, producers need to avoid retaining green stem parts in the combine hopper as much as possible, as they can raise moisture in subsequent storage and result in a grain lot that is more difficult to clean. When combining, try to cut the heads off as high as possible, reducing the amount of straw moving through the machine.

Unlike annual small grains that were bred to have uniform head heights, Kernza head heights are variable. Most growers will want to cut at the bottom of the lowest head, which results in some straw moving through the machine. This isn't

necessarily a bad thing, because the abrasion of spike-on-spike and straw-on-spike is a key part of the threshing mechanism when the cylinder is rubbing the grain against the concave. The volume of biomass flowing through the combine should adhere to the Goldilocks principle of "just right"--too much biomass can lead to plugging and a lack of adequate friction on all spikes for threshing and cleaning, whereas too little biomass can also lead to insufficient threshing and cleaning. Adjust the volume of biomass entering the combine by increasing ground speed in thin and small parts of windrows and by slowing down to pick up thick sections of windrows.

Setting up a combine properly is crucial to getting the cleanest grain product possible. This is always the goal as it will lower cleaning costs and reduce post-harvest storage headaches by preventing contaminants in the grain lot that can cause moisture and heating problems. It is recommended to start with oat settings and tweak from there. Make sure to bring a grain moisture tester to the field. Make a pass and test a sample from the bin–grain should be <15% moisture at the time of harvest. Read carefully the box on combine settings for more guidance on setting up a combine. Remember, combine settings need to be adjusted for each field and harvest timing, as combine efficacy is very sensitive to environmental factors including air temperature and humidity, biomass moisture content, and volume of biomass entering the combine.

Swathing Kernza in western MN; the beginning of harvest activities

Combine settings

Setting a combine properly for Kernza harvest is important to obtain a high-quality grain lot, and will save you money later when cleaning your grain, or paying a cleaner to handle the grain. A clean grain lot requires less air for drying and is less susceptible to fungal contamination.

Before adjusting settings or even leaving the shop, thoroughly clean out your combine. Open traps all over while running combine (i.e. run clean). Sieves need to be cleaned so that they move and *have full range of motion* for best harvest. If you do not do this, you will contaminate your Kernza and risk losing money on the final product. Kernza is a specialty product in an emerging market, and as such, it is critical to maintain robust quality controls.

Rotor setting: When setting up your combine to harvest Kernza, you will need to set the rotor very close to the concave. Set the rotor no more than 1/8 inch away from the surface of the concaves–this maximizes the threshing power of the combine for Kernza. Some experienced growers recommend setting the rotor position so that it is barely hitting the surface of the concave, then back slowly and slightly off from there. Set the rotor (or older cylinder style) speeds as high as you are comfortable doing. The faster the better to allow maximum threshing of the grain while in this area.

Fan speed: Start with your fan speed set relatively low. Have another person follow the combine catching output with a white tarp or sheet. Examine the combine output/residues and keep an eye on the output in the bin. Turn fan speed up slowly until very few straw pieces are remaining in the clean grain in the bin, and until you start seeing seed being blown out of the back as part of the residues. You will need to find the sweet spot between not blowing too much seed out of the back while minimizing undesired residues in the bin. If you can find hulls with fully formed, mature grains within, turn your fan speed down slightly. You need to set the fan tighter for Kernza than most grains. Taking time to get the settings right will make the difference between a frustrating day and a successful and profitable Kernza harvest.

With good combine settings, you should see very few straw pieces in your harvested grain, and a larger proportion of grain will be threshed out of hulls. However, since Kernza is NOT free-threshing, the majority of grains will remain in hulls; this is a trait that breeding programs aim to improve. Be advised that at high fan speeds you may lose some small/immature grains by blowing out of the back of your combine, but do not dial down your fan speed because *achieving a clean sample is more important than capturing all of the small, undersized grains*, which do not contribute to yields. If your fan is set high but you still have straw pieces in your sample, tighten the bottom sieve to send the sample back through the rotor and cleaning process–this should help to clean the sample further.

Sieves: Close sieves up by the separators. Start with the bottom sieve closed–the top sieve is the cleaning sieve. Close the top sieve almost all the way, with a quarter- to half-inch gap opening. Keep checking the grain flowing into the bin–if not clean to your satisfaction, close sieves further (after you have gone through the fan setting procedure). Having threshed grain go through the threshing mechanism two or three times is not damaging to the grain and can result in a cleaner grain in the hopper.

Just-harvested Kernza in the combine bin. The goal is to reduce green stems in the grain lot as much as possible before drying and storage. A) More green stems than ideal. B) Low amount of green material, good for storage and cleaning.

Harvest Troubleshooting

Issue: "I see shattering starting in the field, but more than one third of the spike is still green!"

Solution: Tolerate some shattering to get the spike dried down sufficiently for an effective harvest–it's worth it because green seed can cause nightmares when handling grain in storage.

Issue: Harvested grain in the bin is not always hard and doesn't always "snap" when pinched.

Solution: Stop harvesting and wait a day or two, then moisture test again.

Issue: More than 10% of spikes coming out of the back of the combine still contain grain; not threshing completely.

Solution: Check that rotor is 1/8 inch or less away from the concave, then turn up rotor speed until threshing improves.

Issue: Too much straw is left in the grain product in the bin.

Solution: Turn up the fan speed until grain starts coming out of the back (upon which you should dial back fan speed slightly). After the fan is adjusted, then close sieves further.

Post-harvest handling and storage

Infrastructure Needs (DO NOT start Kernza harvest without these supplies ready):

- Fans for drying – either tube fans that can auger down into grain in totes or gravity wagons, or bins equipped with fans. Full floor aeration is best, if possible.
- Pest-proof storage container like gravity wagons, pro boxes, or metal grain bins with false floor enabling aeration (use false floors for alfalfa or similar size; you must have a base with finer holes than a wheat floor)
- Grain augers
- FIBC bags/grain totes or other container plan for shipping, and a forklift/forks on tractor to lift pallets/bags with.

After harvest is complete, grain should be put on air (run fans and aeration) to keep dry and in condition; grain often "sweats" for the first 24 to 48 hours after being put into storage. Make sure to stir grain after 48 hours to expose all areas to aeration (if not stirred, grain will likely stick to the sides of the bin or storage container). Where grain is stored with full floor aeration, a stirring device may not be necessary to hold grain in condition. If storing grain in a semi trailer, gravity wagon, or grain totes, insert tube fans to move air through the grain. If grain is going into a storage bin, keep fans running for at least a week after loading. If storing grain long-term, check grain periodically and run fans as needed to maintain good grain condition. Inspect grain regularly for rodents, worms and moths. Cover open wagons or trailers with tarps to guard against bird droppings. If you see pests or moths, consider fumigating grain with CO2. As with all food crops, food safety and quality control are important. Make sure Kernza is stored in a rodent and bird protected area. Growers need to also ensure that loading equipment is cleaned out to prevent contamination.

Post-harvest field management

Part of the beauty of Kernza being a perennial plant is experiencing fall regrowth. After harvested Kernza receives at least one-quarter to one-half inch of rainfall, regrowth is initiated from plant crowns. Research has found that fall regrowth is optimized when stubble and residue is removed from the field because it allows light to penetrate to the crown of plants, thereby stimulating regrowth. If swathing, use a draper header swather that cuts straw in large sections to allow baling and removal. If direct combining, chopping and baling off straw is recommended. Straw can be used as feed or bedding (see Chapter 4 pp. 29 for forage quality of summer straw). The quantity of biomass of fall regrowth varies by location and fall growing degree days; expect 0.5 to 4 tons dry biomass/acre in the fall in most areas of the United States. A few cold days below freezing may not halt Kernza growth for the season. Kernza will go dormant after a stretch of about 8 days with temperatures at or less than 28˚ F.

Notes

Moisture levels: Fans and air will NOT dry grain down much more than one percentage point in moisture; they will only keep grain in condition after harvest. For this reason, make sure to harvest at the proper moisture for storage. If you need to use heat and a grain dryer to bring moisture levels down, proceed with caution and use conservative temperatures so as to not damage grain quality–not much is known at this point about heated grain drying with Kernza.

Hull size: Kernza grain does not flow through bins like other grains. Because Kernza has large hulls, large quantities of Kernza will not fully "gravity flow" through combines, gravity wagons, or even cone-bottom bins. Storing in containers with cone bottoms helps grain gravity flow, but you will still likely need to climb in the bin and shovel/sweep grain down. A GrainVac may be helpful in transporting grains out of bins. A larger bin that is less full is more effective when unloading.

Shoveling grain in the grain bin

Marketing Kernza® grain

Kernza grain still has a nascent market and the marketing aspect is not covered in depth in this resource; however, prospective growers should know that Kernza requires special marketing and is not like commodity grains, where you can simply drop grain lots off at an elevator or other facility. Because most plantings don't have guaranteed sales, experts caution growers to understand the economic risks involved with Kernza before planting. Growers do have some options. Two grower-led cooperatives are currently active and can help members market grain:

Perennial Promise Growers Cooperative, based in Minnesota: www.perennialpromise.com

Sustain-a-Grain, based in Kansas: www.sustaingrain.com

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APPENDIX

Intercropping[1]

Growing Kernza offers the opportunity to create beneficial habitat for a wide host of wildlife, including many insect, bird, and mammalian species who have lost significant ground as annually-cropped and tilled acreages have increased across the U.S. Introducing plant diversity into Kernza stands, through intercropping, can further enhance the biodiversity benefits of growing Kernza and, if legumes are used as intercrops, can also offset the need for off-farm N inputs to maintain fertility. Intercropping has been for the last five years, and continues to be, a major area of research and study. While results have been highly variable across studies and sites, some general trends are emerging that can inform decision making around planting and maintaining Kernza+legume intercropped stands. The following conclusions have been drawn from various studies conducted in the Midwest and Kansas:

- Alfalfa, red, and white (and other similar spp.) clovers persist for 3+ years in Kernza stands, compared to other legume spp. that struggle to compete with Kernza. However, in some cases, alfalfa and especially red clover can cause negative competitive effects on the Kernza component of the intercrop.

- Legume intercrops can confer some nutrient cycling benefits to Kernza; however, nutrient benefits of intercropped vs. monocropped stands are not usually observed until the third year of production, or later.

- While not observed in all studies, intercrops in several studies have been observed to decrease Kernza grain yields in years 1 and 2, likely through competition for water and soil nutrients.

- Legume intercrops can significantly improve the forage quality of the stand, whether grazed or harvested for hay, for those using the stand for dual grain/forage production.

- Experimentation and grower innovation in this area is needed, and growers are encouraged to experiment with intercropping on their own farms. However, due to the economic risk involved with potentially decreased grain yields, growers may want to conduct experiments on small areas of their field for several years before intercropping a large area. Tissue tests for plant N content, along with grain yields, can be used to evaluate the benefit or deficit effect of legume intercrops on Kernza stands.

Kernza at the anthesis stage, with a red clover intercrop, in Minnesota.

Kernza Grain Head Anatomy

Dissecting the Kernza seedhead helps understand its component parts, how they dry down, how the hull adheres to the seed, and how to find the Kernza seed. The infographic below depicts the parts of the Kernza spike (seedhead) and plant anatomical terms.

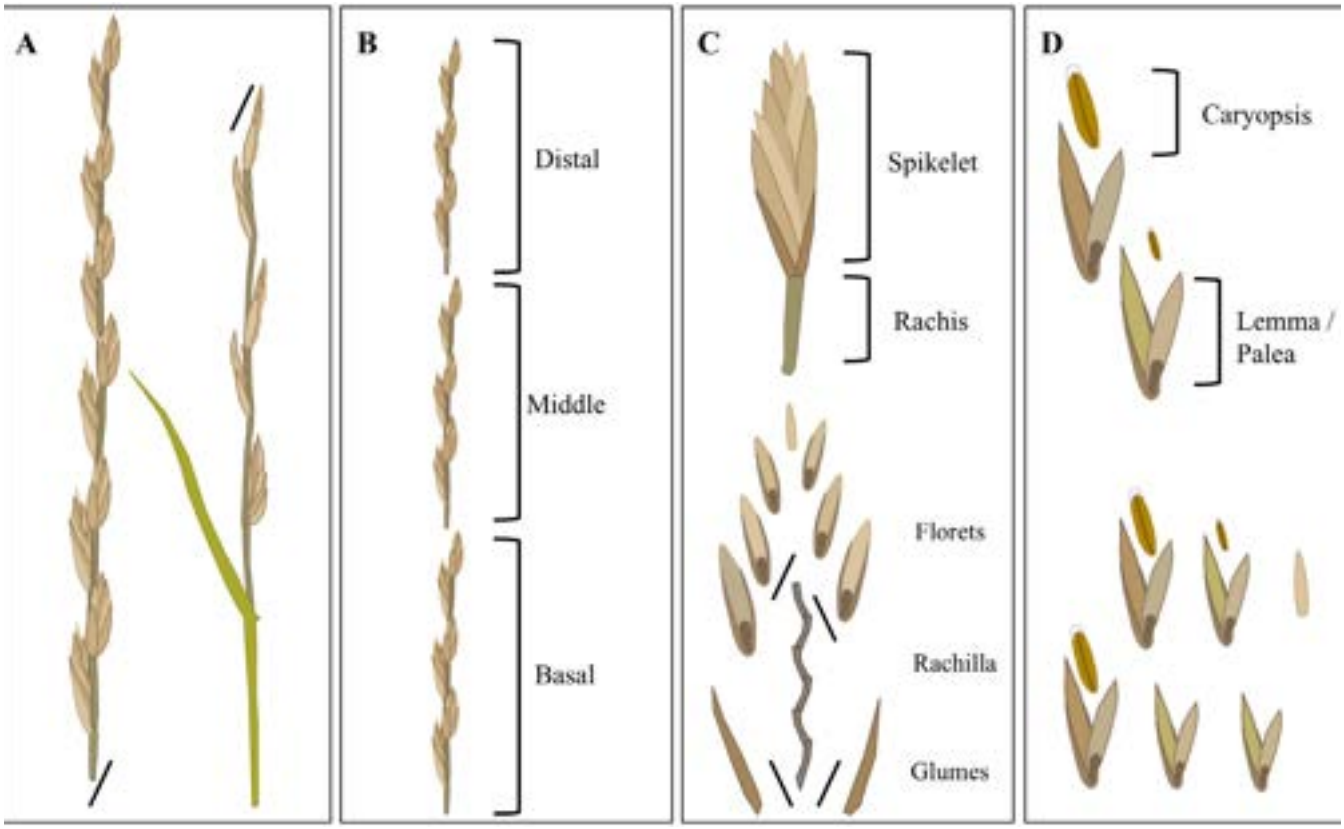

Figure 5. Kernza spike anatomy–finding the seed. Figure credit: Garett Heineck

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Kernza® Identity Preserved Program Guidelines
Revised 2019

1. PURPOSE

The Kernza® Identity Preserved Program (the "Program") is under the direction of The Land Institute. All Kernza® trademark licensees must adhere to these guidelines as referenced in the agreement signed with The Land Institute. The license agreement and the Identity Preserved Program work in conjunction with one another and both are required to be adhered to by growers and handlers of grain that can be sold as Kernza®. The primary purpose of these programs is to provide requirements for the production and handling of intermediate wheatgrass (*Thinopyrum intermedium*) grain that can be sold under the Kernza® brand. Growers producing grain in compliance with these Guidelines (the "Guidelines") will be eligible to sell Kernza® branded grain. The Land Institute also allows its Kernza® trademark to be used by any producer of products made from Kernza® branded grain, provided they become a registered Kernza® retailer or manufacturer, purchase raw material from a registered Kernza® grower who adhered to the Program and Guidelines in the production of Kernza® grain, and comply with The Land Institute's Trademark Usage Guidelines.

2. SCOPE

These Guidelines establish requirements pertaining to the production of Kernza® grain. Currently, Kernza® seed may NOT be held back by growers for additional plantings without the express written permission of The Land Institute. The Identity Preserve Program applies to the phase of production from the planting of parent seed supplied by the Land Institute or another approved seed source as specified in Section 5.2 through to supplying conditioned whole grain to food manufacturers.

2.1 Subcontractors: All subcontractors to licensees must comply with these guidelines. It is the responsibility of the licensee to ensure the proper submission of documentation and maintenance of records.

3. RESPONSIBILITIES

3.1 Kernza® licensee shall:

- 3.1.1 Enter into a Trademark License Agreement with The Land Institute in order to be entitled to produce and market Kernza® branded grain.
- 3.1.2 Meet federal and state requirements regarding sales of agricultural products.
- 3.1.3 Attend specified training sessions as required to participate in this Program.
- 3.1.4 Enroll grain production and acres in the Program.
- 3.1.5 Submit information required for participation in the Program via The Land Institute's online platform (thelandinstitute.submittable.com).
- 3.1.6 Complete Grower's Application prior to first year's planting via The Land Institute's online platform (thelandinstitute.submittable.com)
- 3.1.7 Provide completed Identity Preserve surveys each year prior to harvest via The Land Institute's online platform (thelandinstitute.submittable.com)
- 3.1.8 Provide completed Identity Preserve surveys regarding grain quality by 31 December of each year via The Land Institute's online platform (thelandinstitute.submittable.com)
- 3.1.9 Provide photo documentation for remote field inspection annually prior to harvest via The Land Institute's online platform.
- 3.1.10 Conform to all Program requirements, including these Guidelines.
- 3.1.11 Ensure that all required inspections are completed prior to harvest.
- 3.1.12 Ensure that Program operating procedures and requirements are followed by contract growers, conditioners and other parties performing tasks related to Kernza® production.
- 3.1.13 Use the Kernza® brand properly to identify only product that has been determined to have met Program requirements and in compliance with the Trademark Usage Guidelines.
- 3.1.14 Permit access for inspection by the Land Institute or its agent to production sites(s), subcontractor sites, storage sites, processing facilities and records by appointment.
- 3.1.15 Submit samples of grain to Northern Plains Grain Inspection or other approved laboratory for toxin, moisture, and purity testing as specified in Section 11 of the Identity Preserve Program.

3.2 The Land Institute (or its agent) shall (subject to payment by grower of any applicable fees):

3.2.1 Evaluate each application submitted to:
- 3.2.1.1 Ensure Program participation requirements have been met.
- 3.2.1.2 Ensure all required information has been provided.
- 3.2.1.3 Identify obviously non-conforming applications prior to inspection.

3.2.2 Approve Grower's Application prior to first year's planting
3.2.3 Provide Trademark licensing agreements to approved growers
3.2.4 Provide Identity Preserve surveys each year prior to harvest for agronomic surveys and prior to 31 December for grain quality surveys via The Land Institute's online platform (thelandinstitute.submittable.com)
3.2.5 Evaluate photo documentation for remote field inspection annually prior to harvest via The Land Institute's online platform and communicate regarding any obvious issues
3.2.6 Respond to questions regarding the Identity Preserve Program within 60 days of submission.
3.2.7 Report field inspection results to producers.
3.2.8 Determine product conformity to standards based on submitted results
3.2.9 Monitor use of the KERNZA® mark and branding elements for conformity.
3.2.10 Monitor the Program to validate the effectiveness of the system in achieving the Program objectives.
3.2.11 Maintain a list of approved seed strains (varieties, populations, sources, or seed lots) in Section 5.2
3.2.12 Maintain a list of approved seed suppliers at Kernza.com beginning December 2019.
3.2.13 Maintain a list of approved seed conditioning facilities at Kernza.com beginning December 2019.
3.2.14 Maintain a list of registered Kernza® retailers and manufacturers.
3.2.15 Facilitate interaction between growers and buyers of Kernza® Grain
3.2.16 Provide access to most recent research results
3.2.17 Make efforts to build strength in the Kernza® brand
3.2.18 Help develop markets for Kernza® seed and grain

4. APPLICATION FOR PRODUCTION

4.1 Producer shall apply to The Land Institute (or its agent) on the Grower Participation Form supplied by The Land Institute at thelandinstitute.submittable.com to become a registered Kernza® Grower
4.2 Producer shall submit application including all required documentation by the 31st of December in the year of seeding.
4.3 Applications shall include:
- 4.3.1 Map describing field location
- 4.3.2 Identity and source of seed used/quantity to be planted
- 4.3.3 Field number – unique to each field
- 4.3.4 Planted area
- 4.3.5 Producer's agreement to:
  - 4.3.5.1 Adhere to program requirements.
  - 4.3.5.2 Permit access to The Land Institute (or its agent) for performing required inspections and examining required records.

4.4 Late applications, made after the 31st of December in the year of seeding, may result in denial for certification. A late application fee will be assessed.

5. FIELD STANDARDS

5.1 Land requirements – producer shall prepare field by destroying all weedy growth and vegetation from a previous crop.
5.2 Seed requirements
- 5.2.1 Seed shall be from a genetic strain approved by The Land Institute.
- 5.2.2 Kernza® producer shall obtain seed from a seed source approved by The Land Institute.

5.2.3 Written permission for use of a Kernza® seed source other than provided directly by The Land Institute or another approved source (list maintained at Kernza.com beginning 31 December 2019) must be given by The Land Institute.

5.2.4 Concurrent with requests being made for exemption to 5.2.2, documentation must be provided in accordance with Section 10. Documentation does not guarantee exemption.

5.3 Planting equipment shall be cleaned thoroughly prior to seeding enrolled field.

5.4 Kernza® production fields shall:

5.4.1 Be separated from adjacent fields by a minimum of 5 feet.

5.4.2 Not contain undesirable species in excess of amounts allowed in Section 10.4

5.5 When The Land Institute withdraws approval from a previously approved seed source, harvests will be permitted from fields planted from these seed sources for up to three years following the date of withdrawal of approval.

6. FIELD INSPECTION

6.1 Fields may be inspected by The Land Institute (or its agent) either in person by appointment or via submitted photograph

6.1.1 In person field inspections may include data collection for research purposes

7. HARVESTING, STORAGE AND HANDLING REQUIREMENTS

7.1 Producers and handlers of Kernza® seed, grain or other products are responsible for thoroughly cleaning all equipment used for harvesting, conveying, storing, handling, and conditioning before handling.

7.2 Stored product must be identified at all times.

7.2.1 A bin or lot number must identify all bins.

7.2.2 The contents of bins must be identified with an attached bin label and associated bin record.

7.2.3 Containers must be labeled with a stenciled lot number or a tag securely fastened to the bag.

7.2.4 Lot or bin numbers should include identifiers for the farm

8. CONDITIONING REQUIREMENTS

8.1 Conditioning facilities shall be approved by The Land Institute (or its agent) prior to handling Kernza® seed, grain or other product via their online platform (thelandinstitute.submittable.com)

8.2 Facility must preserve the identity of the product at all times.

8.3 Approval of conditioning facilities shall be on an annual basis via renewed trademark license agreement with the organization owning the facility.

8.4 Facilities handling Kernza® destined for sale as a food product shall submit evidence of inspection for food safety standard compliance.

9. SAMPLING

9.1 Grower shall draw and retain a sample from each field harvested as the product is conveyed into the storage bin.

9.2 A representative sample of each conditioned lot shall be drawn by an authorized sampler according to designated sampling procedures

9.3 The sample shall be submitted to a designated laboratory for testing along with information necessary to complete certification.

9.3.1 Designated laboratories include Northern Plains Grain Inspection

9.3.2 Written approval of other laboratories may be given by The Land Institute at its discretion.

9.4 The Land Institute shall determine the tests to be performed.

9.4.1 Current tests on Kernza® destined to be food to be performed include: Purity, DON, moisture and protein.

9.5 Product shall be tested and analyzed in accordance with the procedures prescribed by The Land Institute

9.6 Test results shall be submitted to The Land Institute (or its agent) via its online platform and evaluated for conformance to quality standards.

9.7 The Land Institute (or its agent) shall determine the certification status of all lots for which Program certification has been requested within 60 days of submission of required data.

10. SEED STANDARDS

10.1 The Land Institute shall designate sources approved to be used for seed.

10.2 Lots to be used for seed must comply with all applicable seed law requirements.

10.3 Seed should be produced in accordance with specific standards to ensure quality grain production:

- 10.3.1 Isolation
  - 10.3.1.1 Seed production fields shall be separated from other intermediate wheatgrass by a minimum distance of 165 feet.
  - 10.3.1.2 Seed production fields shall be separated from inseparable other crops by a distance adequate to prevent mechanical mixture.
- 10.3.2 Seed Quality Standards
  - 10.3.2.1 Pure seed (minimum) – 90%
  - 10.3.2.2 Total Weed Seeds (maximum) – .5%
  - 10.3.2.3 Restricted Weed Seeds (maximum) - 9/lb.
  - 10.3.2.4 Other Crop Seeds (maximum) – .5%
  - 10.3.2.5 Inert matter (maximum) – 10%
  - 10.3.2.6 Germination (minimum) – 80%

10.4 Seed may NOT be held back for additional plantings without the express written permission of The Land Institute.

11. GRAIN QUALITY STANDARDS

11.1 Some varieties are expected to be genetically free-threshing, producing naked seed. Others are expected to largely remain in-hull. Non-free-threshing types will require dehulling for most purposes, but may be desirable for direct use in malting. Different quality standards may be established for "in-hull" and "naked" grains.

11.2 Kernza® seed and/or grain shall not exceed 13% moisture.

11.3 Kernza® grain shall not exceed 1ppm DON

11.4 The following special grades shall be prohibited:

- 11.4.1 *Ergoty Kernza®.* Kernza® seed and/or grain that contains more than 0.1 percent of ergot.
- 11.4.2 *Garlicky Kernza®.* Kernza® seed and/or grain that contains in a 1,000 gram portion more than two green garlic bulblets or an equivalent quantity of dry or partly dry bulblets.
- 11.4.3 *Light Kernza®.* Kernza® seed and/or grain that has an unmistakable odor of smut, or which contains, in a 250-gram portion, smut balls, portions of smut balls, or spores of smut in excess of a quantity equal to 5 smut balls, but not in excess of a quantity equal to 30 smut balls of average size.
- 11.4.4 *Smutty Kernza®.* Kernza® seed and/or grain that contains, in a 250-gram portion, smut balls, portions of smut balls, or spores of smut in excess of a quantity equal to 30 smut balls of average size.
- 11.4.5 *Treated Kernza®.* Kernza® seed and/or grain that has been scoured, limed, washed, sulfured, or treated in such a manner that the true quality is not reflected by either the numerical grades or the U.S. Sample grade designation alone.

12. RECORD REQUIREMENTS

12.1 Producer shall retain records for three years following final sale from an enrolled field.

12.2 Records of all operations relating to the program shall be complete and adequate to account for all incoming product and final disposition of product and shared with The Land Institute via its online platform (thelandinstitute.submittable.com)

12.3 Producer shall submit all records requested by The Land Institute through its online platform, including management practices, locations of acreages, harvest and post harvest techniques, and buyer contact information.

12.4 Handlers shall submit to The Land Institute (or its agent) of all records pertaining to the Kernza® product or ensure that their contracted producers do so.

12.5 Required records:

12.5.1 Maps describing field locations.
12.5.2 Invoice and tags from seed planted.
12.5.3 Planting records.
12.5.4 Management practices and requirements
12.5.5 Harvest records including dates, amounts and any destroyed product.
12.5.6 Storage records including assigned bin numbers
12.5.7 Grain quality information
12.5.8 Purchaser information
12.5.9 Records of product movement
12.5.10 Sales records (pounds sold).
12.5.11 Current inventory of eligible product.
12.5.12 Quality Assurance program records – (applications, inspection reports, etc.)

13. MARK OF CONFORMITY

13.1 Product meeting Program requirements may be labeled as Kernza® brand grain.

13.2 Proof of conformity shall accompany all sales and transfers of eligible product and shall be provided to all buyers at the time of delivery.

13.3 Product shipped without proof of conformity shall not have met Program requirements and will be deemed to be non-conformant.

14. SANCTIONS FOR MISCONDUCT

14.1 It is the responsibility of each Program participant to abide by the rules, adhere to the standards and report irregularities or violations.

14.2 Intentional violation of program requirements and/or misuse of marks of conformity may result in suspension from program participation.

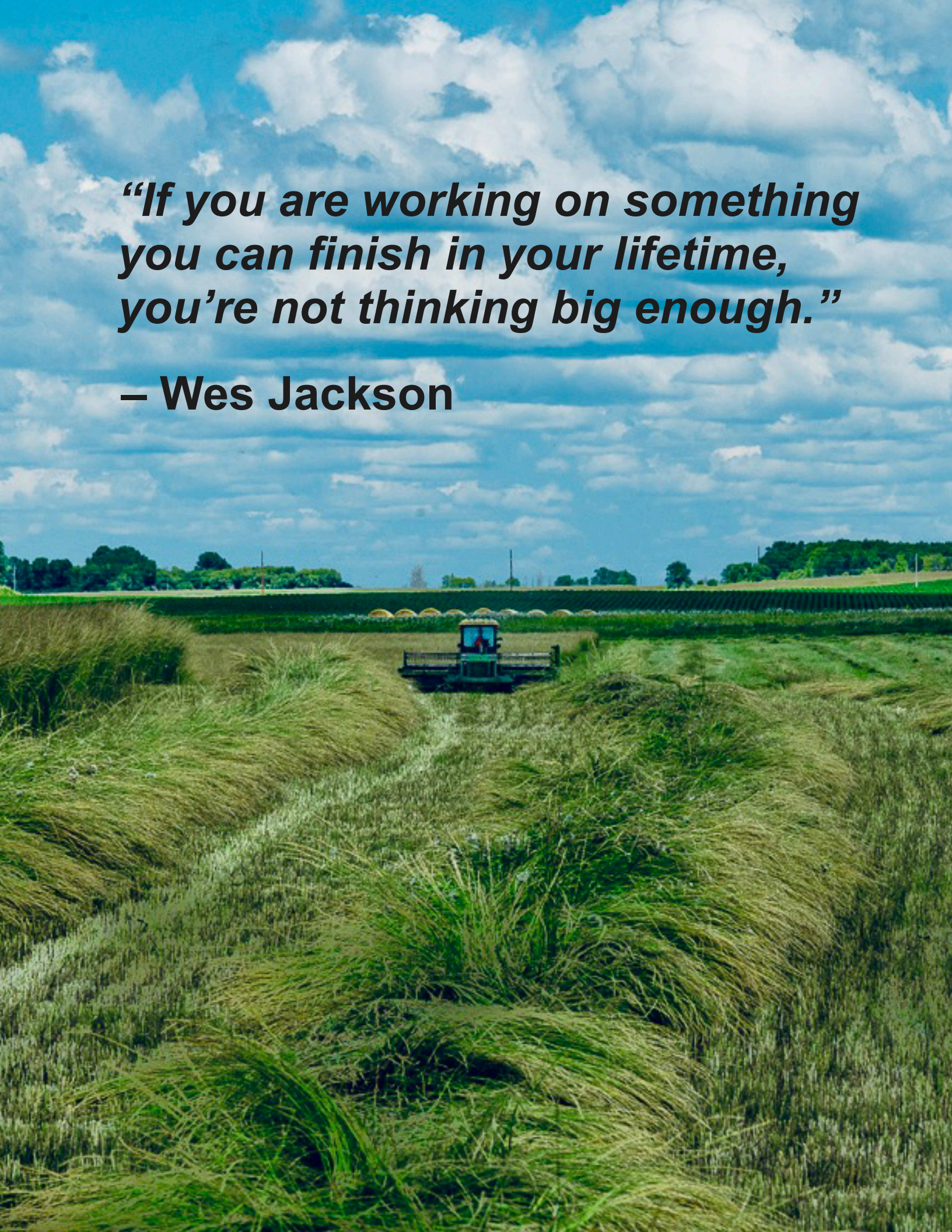
14.3 Decisions to suspend participation in the program due to misconduct shall be made by The Land Institute.

14.4 Appeals or petitions for reinstatement shall be directed to The Land Institute.

15. FEES

15.1 Producers shall be responsible for all Kernza® IP Program participation fees

15.2 The Land Institute shall determine royalty fees to be assessed on sales of Kernza® branded seed and grain products in accordance with Trademark Licensing agreements.


“If you are working on something you can finish in your lifetime, you’re not thinking big enough.”
– Wes Jackson