Final Report for "Grain and Forage from Intermediate Wheatgrass:
A New Perennial Grain Crop"

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Project Highlights

- One of the first studies to investigate dual-use of intermediate wheatgrass (IWG) for production of Kernza® grain and forage
- Sites in Minnesota and Michigan represent a wide gradient of Upper Midwest soil-climate conditions on organic soils
- Both mechanical clipping and livestock grazing were tested
- Results show that IWG stands can yield substantial quantities of high-quality forage while also producing Kernza grain
- Projects reached farmers and agricultural professionals through field days and meetings

Minnesota Highlights	Michigan Highlights
• Spring forage increased dramatically in the second year, due to better stand establishment • Straw yield was substantial (over 1 ton/acre) • Forage harvest did not affect grain yield • However, spring forage harvest did increase weed pressure in the second year • Harvesting forage in both spring and fall maximized forage production • Grain yields averaged from 70-350 lb/acre. • Farmer collaborators have found value in IWG forage, both for hay and grazing • Research has been highlighted at three field days, at large winter meetings, and in an extension document • We are continuing data collection at both on-station and on-farm sites through 2019	• Interplanting IWG with buckwheat reduced weed competition in the first year of crop establishment • Too much nitrogen from manure induced lodging, even in a sandy-loam soil • Farmer collaboration with this project is unique, a farmer with animals and seeking grain for flour (a miller/baker) • To promote IWG and feature the dual usage, 2 field days were held at each site (4), KBS and Hampshire farm, and will again be held in 2019 • Yields of IWG forage and seed were modest (50 -700 kg/ha per harvest), but not reduced by grazing. Forage quality (NDF) was higher in grazed IWG. • As a new dual use crop, there is potential to promote use by NRCS to include in EQIP programs, yet agronomic research is still needed on establishment, weed management and optimizing growth

Overview

Intermediate wheatgrass is the first perennial grain being domesticated on a commercial basis. The grain is being marketed under the trade name Kernza®. It provides opportunity for economic return as well as benefits to soil health, soil conservation, and carbon sequestration. Our objective is to determine the potential for intermediate wheat grass (IWG) to be used as a multi-functional, dual-use cropping system to produce both grain for humans and forage for livestock. An added value for many farmers is the straw, used for animals or mulching. We are conducting experiments to examine the effects of spring and fall forage harvest, as well as fall grazing on yield and quality of IWG forage and grain. In addition, we will evaluate the effect of hoof traffic and grazing on long-term stand productivity. This project is taking place on farms in Minnesota and Michigan. Complementary research is also being conducted using the organic dairy at the West Central Research and Outreach Center, Morris, MN. Results will be used to determine how grain and forage outputs can be maximized through agronomic management to enhance farmer profitability and environmental sustainability. Products from this research include peer-reviewed, open-source research articles, field days, and a best-management guide designed for organic farmers. This project ran from fall of 2016 to summer of 2019 and is now complete. Follow-up work is continuing using separate funds.

Minnesota research in 2017

The IWG fields that were seeded in fall of 2016 at M. Jorgensson and J. Theis Farms suffered severe winter injury that resulted in poor establishment in 2017. Stand failure was attributed to a combination of a late seeding date in October and a December rain event that resulted in ice sheeting. We were unable to collect any data from these two locations in 2017. We re-established the experiments on these farm sites in September 2017 and achieved promising stands.

At the organic research farm in Morris, MN, forage yields in the spring following establishment were only 0.1 tons per acre (Figure 1). Kernza forage biomass yields averaged 0.7 tons per acre when harvested in fall after grain harvest (Figure 2). The spring harvest did not affect fall forage yields. Straw production at grain harvest averaged 1.25 tons per acre and was not affected by spring forage harvest (Figure 3). Kernza grain yields were roughly 350 pounds per acre. A spring forage harvest did not affect summer grain yields (Figure 4). While the forage yield was low, these results show that there is potential for early season harvests without affecting grain yields.

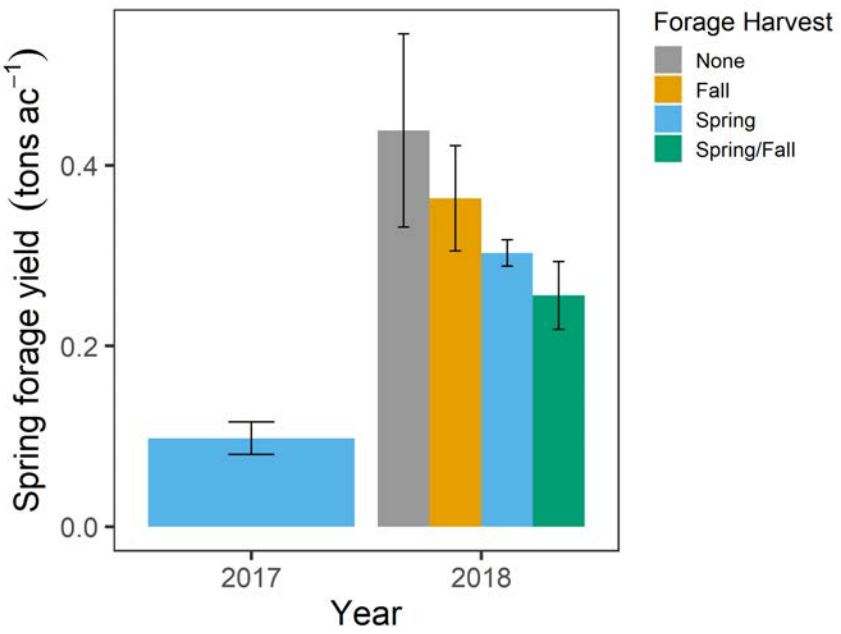


Figure 1. Kernza spring forage biomass yields by year and harvest treatment. Since the fall clipping had not occurred yet in 2017, the spring and spring/fall treatments are pooled.

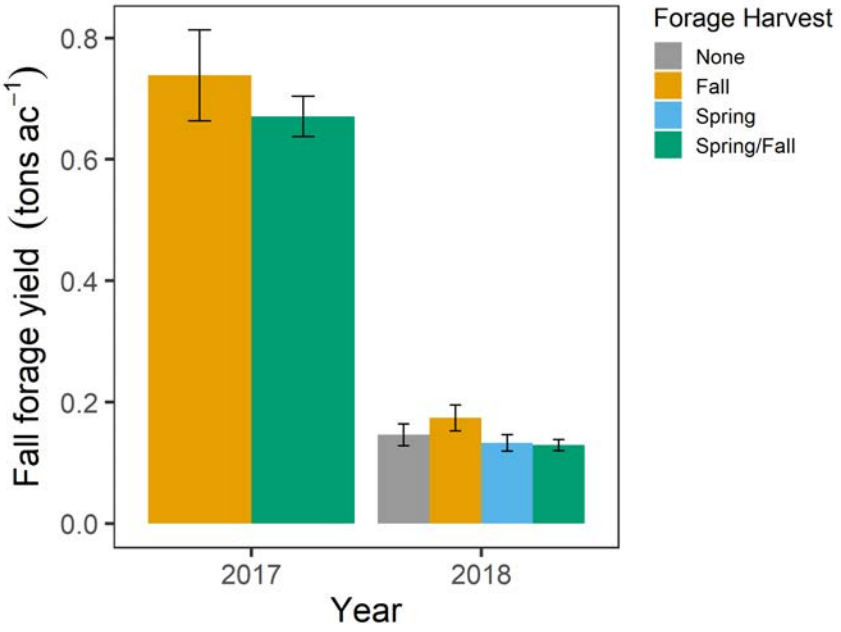


Figure 2. Kernza fall forage biomass yields by year and harvest treatment.

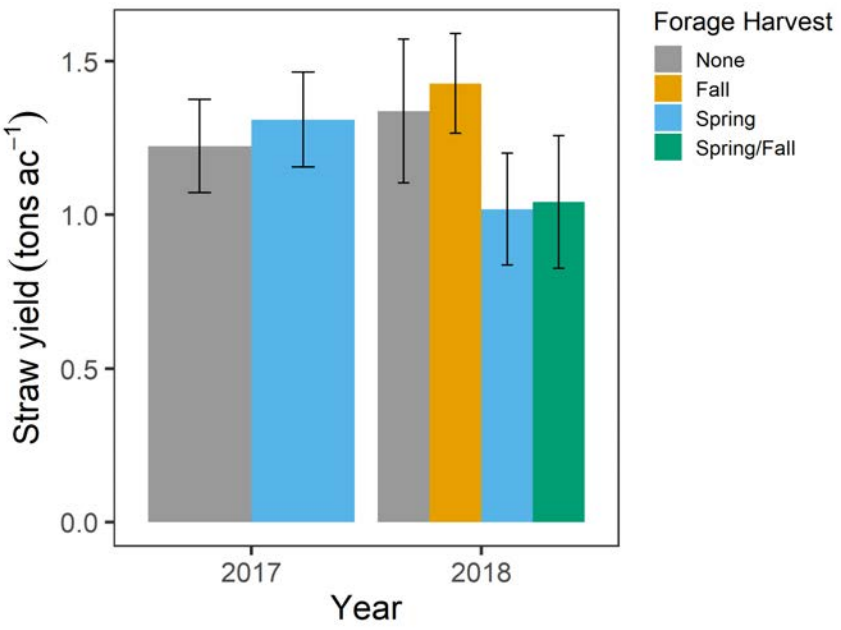


Figure 3. Kernza straw yields by year and harvest treatment. Since the fall clipping had not occurred yet in 2017, the none and fall treatments and the spring and spring/fall treatments are pooled.

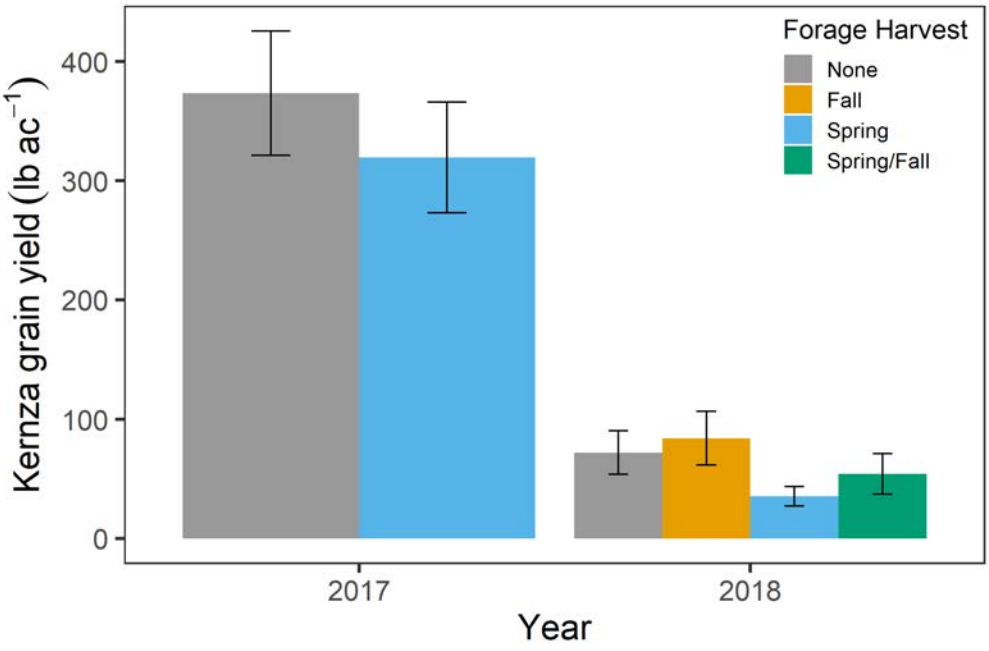


Figure 4. Kernza grain yields by year and harvest treatment. Since the fall clipping had not occurred yet in 2017, the none and fall treatments and the spring and spring/fall treatments are pooled.

Annual weeds were present in our intermediate wheatgrass stands because we had no control options (Figure 5). Weed biomass may have reduced grain yields due to competition, as weed biomass was nearly one third that of IWG biomass. Weed biomass was not affected by spring forage harvest.

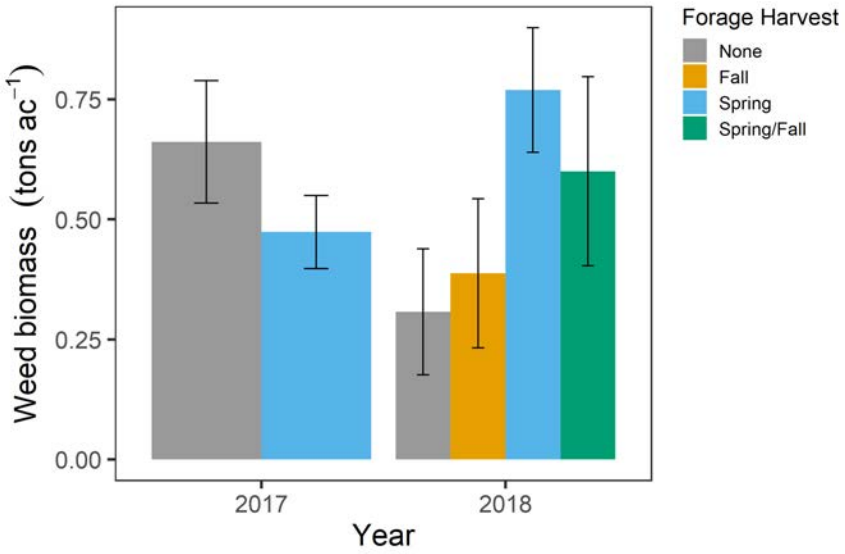


Figure 5. Weed biomass at grain harvest by year and harvest treatment. Since the fall clipping had not occurred yet in 2017, the none and fall treatments and the spring and spring/fall treatments are pooled.

Minnesota research in 2018

Research continued at the organic farm in Morris, MN and the on-farm sites. The Kernza at the Theis farm site overwintered well and came back vigorously in the spring of 2018. Due to lack of access to a combine, the field was harvested for hay in July of 2018. The farmer reported that the cattle performed well on the Kernza hay. In the fall, plots were established to enable graze and no-graze treatments, and beef cattle grazed the plots in October (Figures 6 and 7). Forage availability on average was 1.1 tons per acre and animal intake was over 0.6 tons per acre, with a residual height of five inches. Grain yield will be measured in these grazed and ungrazed plots in August of 2019. The second attempt to establish Kernza at the Jorgenson farm failed, likely due to excessively wet spring conditions, so the site was abandoned.

Figure 6. Grazed (left) and ungrazed (right) plots at the Theis Farm on November 2, 2018.

Figure 7. On-farm Kernza cattle grazing in spring.

The spring forage yield at Morris was much greater in 2018 than in 2017, averaging 0.3 tons per acre (Figure 1). This is likely because the stand had a more established root system and was able to invest more resources in aboveground growth. Forage harvest the previous year did not reduce spring forage yield, statistically speaking, but there was a trend toward lower yield with more frequent harvest the previous year.

Fall forage yield dropped substantially in the second year, to less than 0.2 tons per acre (Figure 2). This was likely because the weather was very cool following grain harvest, so there was little opportunity for regrowth. Previous forage harvest did not affect forage yield in the fall.

Straw yield remained stable across the two years, at roughly 1.2 tons per acre (Figure 3). There was a trend (not statistically significant) toward lower straw yield in the treatments that were clipped in the spring.

Grain yield dropped substantially in 2018, to an average of 70 pounds per acre (Figure 4). This pattern is commonly seen in IWG fields and is the subject of ongoing research. None of the forage harvest treatments affected the rate of grain yield decline, indicating that there is little tradeoff between forage and grain production. However, spring defoliation did reduce the number of spikes ha^{-1} (data not shown), indicating that there is a risk of damaging the stand with mechanical forage harvest. In addition, soil tests revealed that the level of available phosphorus in the soils at the study site is very low; this may help explain the lower-than-expected yields. Additional manure applications and foliar phosphorus applications have been applied to determine the potential for a yield response in 2019.

Weed pressure at grain harvest was similar on average in both years, but in 2018 spring clipping increased weed pressure (Figure 5) This is likely because it opened up the canopy and reduced competition with germinating weed seeds. This problem could be mitigated in the future by adjusting the timing or severity of spring defoliation.

Overall, our results indicate that there is potential to produce a substantial quantity of high-quality forage biomass with spring and fall clippings, up to 1.2 tons per acre over two years, without reducing Kernza grain yield. Harvesting biomass in both spring and fall resulted in the highest yield (Figure 8). While weed pressure was substantial and may have reduced yield, the IWG nevertheless maintained a vigorous stand.

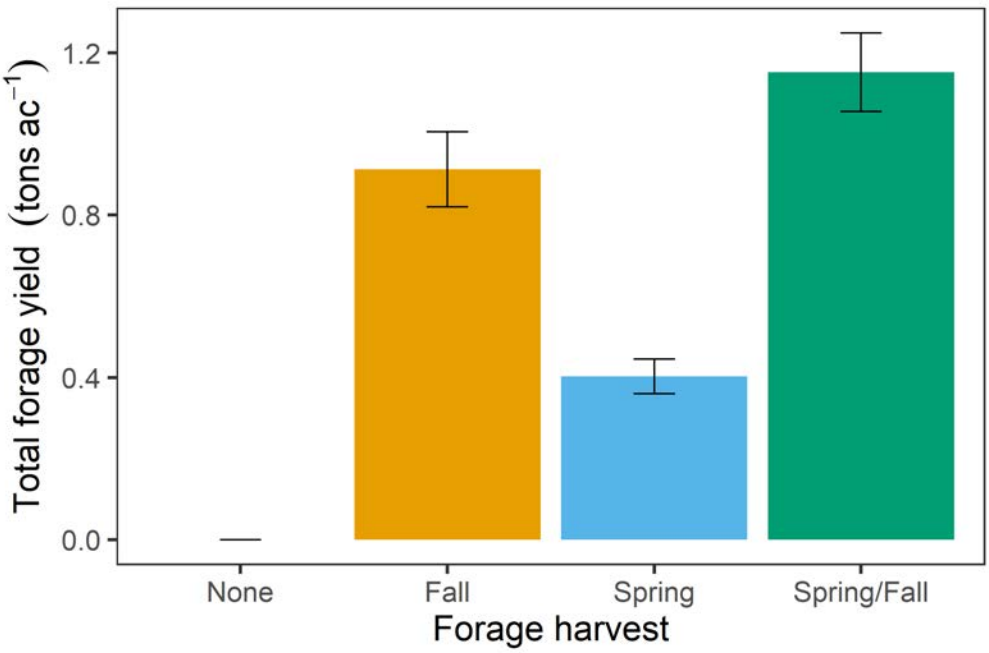


Figure 8. Cumulative two-year forage yield (not including straw) by forage harvest treatment.

Minnesota research in 2019

Data collection is continuing for an additional summer using separate funds. The spring clipping was applied to the research station site in Morris on May 29, 2019 (Figure 9). Grain and straw yield and weed pressure were measured in August, and fall forage yield will be measured in October. This will result in three years of data from this experiment. The IWG stand looks stronger and healthier this year than ever before, indicating one of the benefits of a perennial growth habit. Anecdotally, weed pressure appears to be lower this year than in past years. Continuing the experiment through the end of 2019 will show how forage biomass removal affects yields as a Kernza stand ages.

Figure 9. Clipping treatments applied in spring 2019.

Minnesota outreach in 2018

The research plots were featured at the Morris Organic Dairy Day on August 14, 2018. We presented an overview of Kernza's economic and environmental benefits and prospects for variety improvement. We then held an interactive discussion in the field by the plots, discussing dual-use and other management questions. There were 84 total participants, including 67 farmers.

Results from this study were also highlighted at two summer field days related to source water protection. One field day was on August 22 in Chatfield, MN, and the other on August 23 at Lincoln Pipestone Rural Water Kernza planting in Verdi, MN, each one with about 50 attendees.

Minnesota outreach in 2019

Results from this study were shared at the MN Kernza Farmer-Researcher meeting on March 11, 2018. This event drew over 55 attendees, including farmers, representatives of government agencies, commercialization partners, and researchers. The presentations from this event will be published on YouTube in the coming weeks, providing the first public webinar-style information about Kernza management. In addition, this study informed the Kernza Management Document, the first-ever extension publication related to managing IWG for grain and forage production. This document was released at the meeting on March 11 and will be posted on Kernza.com in the coming weeks. The results from this study were highlighted again at an on-farm field day on July 11, 2019. In addition, We highlighted this research at the the Morris 2019 Organic Dairy Day on August 13, including a talk and a field walk. There weas considerable producer uinterest in this research.

II. Intermediate wheat grass in organic systems in Michigan

Visit: http://pwheat.anr.msu.edu/

A team of Michigan State University collaborated with the University of Minnesota to access the impact of grazing and grain harvest on intermediate wheatgrass. Test plots were conducted on certified organic fields. Certification of fields in Michigan is performed by Global Organic Alliance. The Michigan team included Dr. Sieglinde Snapp (soil health), Dr. Kim Cassida (pasture management), and Vicki Morrone (extension and on farm management) along with farmer collaborator, Randy Hampshire. The research was conducted on three certified organic plots, Kellogg Biological Station (KBS) (3.5 acres, 2 plots) at Michigan State University in Hickory Corners, Michigan and on-farm at Hampshire Farm (2 acres) owned and managed by Randy Hampshire in Kingston, Michigan, located in north-east Michigan of the lower peninsula.

Grazing Treatment

At both locations in both years (2017 & 2018), cows were released in the fall for two to three days into the grazing treatment plots until 5 in height remained of growth. At the KBS site, 12 steer in year 1 and 15 steer in year 2 were released on the plots, managing the herd to accommodate the treatments (**see MSU/KBS Plot Map Figure**). Two treatments were replicated three times in the KBS site, Treatment 1 = no grazing and only harvest of grain in late summer and Treatment 3 = Harvest in summer then grazing in the fall). At Hampshire Farms Jersey Heifers were released for two days each, offering them free access to these pastures. They freely chose the area over their mixed pasture site of timothy grass and clover (and weeds of course). At this on-farm site we had two treatments, one with and one without pasture grazing in the fall. Both plots (1 acre each) were harvested for grain and straw.

Crop Establishment and Production-

The crop was planted in the fall of 2016 at each site. At KBS it was planted on September 24, 2016 following application of 27,215 kg/ha dairy slurry then four passes with the chisel plow followed by soil finishing. At Hampshire Farm the soil was prepared by disking, then applying 20 tons/acre of cow manure and incorporated with a final disking, on October 1, 2016. Seed was drilled at each site at a rate of 12# to the acre.

Michigan's Observations for best practices

To help assure this perennial crop is well-established and overwinters in its initial year, it must obtain adequate growth following seeding. Planting into moisture facilitates good establishment as well as interplanting with an annual crop such as buckwheat to serve as a nurse crop, noting the annual will winter-kill leaving the intermediate wheatgrass to continue growing in the early spring. As the grain matures in the summer, harvest must be timed carefully to reduce seed shattering.

Therefore, it has been noted that it is best to winnow the crop following grain maturity but prior to complete drying. The field is winnowed, allowed to dry for a day or two then carefully combined to retain maximum grain. Rain fall is especially needed following grain harvest in the first production year. Without rain at this time, weeds can easily outcompete the young plants. In the second year, the crop typically produces more tillers, providing weed competition. Water, of course is still essential to produce pasture for the upcoming fall and crop survival. These environmental essentials are cause for farmers to make the call annually whether to harvest grain and/or use the fields for pasture, based on the weather of that season and the need to additional pasture. Because of these unpredictable variables, we need to continue identifying best management practices for this crop's production methods when used as a multi-purpose crop. Additionally, post-harvest practices are needed to identify effective and efficient ways to hull the grain, as it is a very small grain.

Sample Process-Michigan

Harvests were collected using 1 m^2 clips from each treatment. All samples were collected in spring, summer and fall at each site (with exception of the initial year spring at KBS). Weeds were separated from intermediate wheatgrass stems in summer clip samples to estimate weed competition. Samples were dried in 60° C dryers until moisture was apx 15%. Weights of bags and samples were taken then grain was hulled, weighed and ground. Plant tissue was also ground for each sample at each site. Nutrient analysis was run for these samples to test animal feed qualities.

2017-2018 IWG Research-Michigan

The plots were established in the fall of 2016, drilling the seed, obtained from The Land Institute, Lee DeHaan. Hampshire Farms tilled 2 acres, added 20 tons/acre (2.24 tons/ha) of raw dairy manure, then drilled and inter-planted buckwheat (12#/ac) as a nurse crop with the intermediate wheatgrass seed on October 1, 2016. The grain was harvested on August 3, 2017, flail mowing then combining the seed the following week. Subsamples of biomass and grain were collected for yields and quality assessment. Prior to grazing each year, in October, a subsample of the grass was collected to conduct digestibility analysis and calculate pasture biomass.

In 2018 each field at Hampshire Farm Herbruck's dried poultry fertilizer was applied at a rate of 1 ton/acre testing at 4-3-2 on June 18, 2018. The grain, 271# per acre with hulls was harvested on September 23, 2018 following the same procedure as the previous year. At the KBS field a split application of Herbrucks 4-3-2 dried poultry manure was applied on March 7, 2018 and November 4, 2018.

Extension opportunities for farmers to learn about the IWG on-farm performance in Michigan

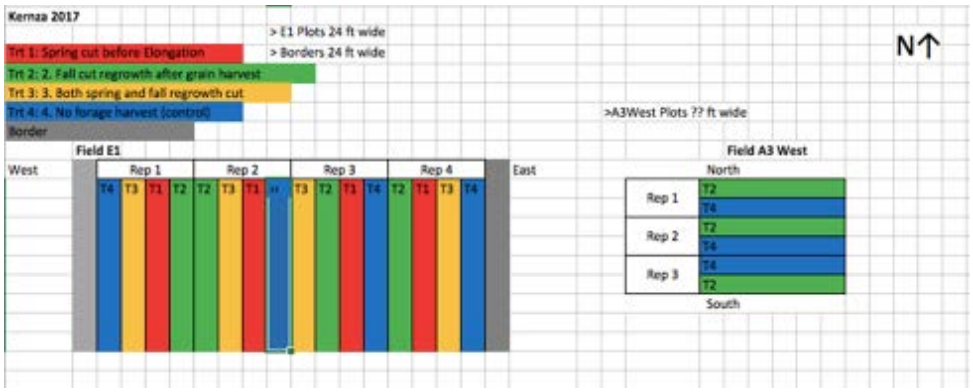
In 2017 we held two field-days, one at Hampshire Farms (October 30) and the other at the Kellogg Biological Station (November 3). Each of these events included bringing cows on the pasture to graze the pasture to demonstrate the pasture

portion of the research. The cows resided on these pastures for 2 days, removing the cows when the grass was grazed down to about the growing point, 5 inches. The 2017 field days brought 8 agriculture persons to Hampshire Farms (heavy rain that day) and approximately 45 agriculture related persons (farmers, extension and agri-dealers) attended the Kellogg Biological station field day located in Hickory Corners, MI. Farmers, especially livestock farmers were excited about the prospect of a crop that offers an extended grazing season in addition to providing valuable environmental benefits. Seed vendors showed a keen interest in the potential of a new forage that is adapted to dry, hot weather (following establishment), and has multiple qualities to offer in terms of grain, pasture, straw and leaching minimization that does well in the North Central region.

In 2018, the field day event was offered again at the field two sites. At KBS, the intermediate wheatgrass was well established with minimal weeds. This was year 2 of the crop's establishment. The field day participants especially appreciated the dual usage qualities of the crop (grain and fodder) in addition that it provides quality straw, which is especially valuable to animal and vegetable farmers. The field day at Hampshire Farm was held in conjunction with a planning meeting for a Michigan organic flour coop. The farmers attending had a focus of flour so were most interested in the nutritional analyses of the grain. Since the flour coop was just being planned they were not ready to embrace the production of this crop but acknowledge that they have access to Hampshire's grain harvest for future testing such as hulling and milling.

During the initial year of the grant, Kellogg Biological Station had two research plots, one with two treatments, grazed and ungrazed but all grain and straw was harvested and removed from the fields due to concern that it would smother regrowth. The smaller of the 2 plots (E1) did not offer a means to graze using animals so grazing was simulated via mowing. Due to initial poor stand and weed infestation this smaller plot was abandoned following 2017 data collection. The field treatments at Hampshire Farms consisted of an acre of grazed and an acre of not grazed but grain and straw were harvested in both plots.

From each treatment plot, one meter^2 subsamples were collected, dried and analyzed. The treatments included 1. grazed and 2. ungrazed and the whole field was harvested for straw and grain at the two locations. In year 2017 treatments at KBS E-1 field included four treatments; 1. Spring cut before stem elongation, 2. Fall cut after grain harvest, 3. Both spring and fall regrowth cut and 4. No forage harvest (control). Each of these treatments were replicated 4 times and ½ of the overall plot was grazed, adding a sub-treatment to the plot. Note that field E1 is the field that was abandoned due to excessive weeds. In the KBS A3 field, there were two treatments and three replications. This is the field that was treated using cows to graze the plots. This field was used during the duration of this project.



Grain, forage production and forage quality analyses at Michigan Sites

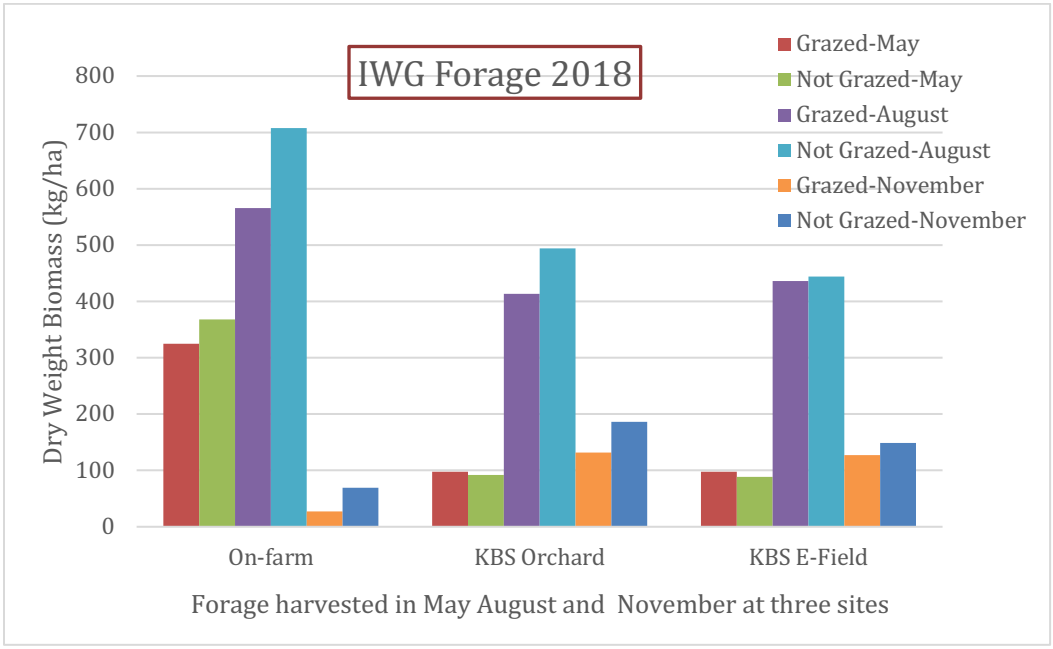
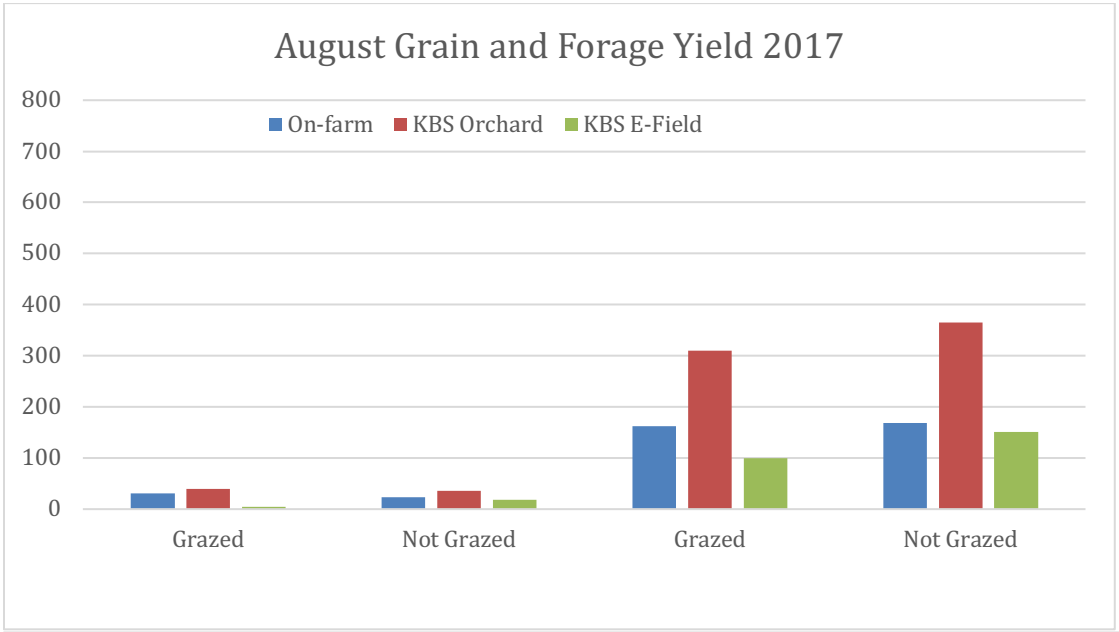


Figure 11. Forage harvest over the season monitored in May, August and November is shown for grazed and not grazed (control) at three sites (Hampshire farm, KBS orchard site and KBS E-field site). Very similar trends were seen in 2017 and 2018, with no effect of grazing observed on forage biomass produced at any site or harvest. Yields were higher at the on-farm site, but at none of the sites were forage yields over 800 kg/ha dry weight, consistent with a modest forage yield potential under these conditions. Weed biomass was about one-third the total biomass at fall harvest-figure. time points, indicating that weed control needs to be improved. This continues to be a challenge in organic IWG production systems.

The August harvest included seed measurements, as shown in Figure 12A (2017) and Figure 12B (2018). Plant growth overall was higher in 2018, in the second year

after establishment, as has been observed previously for IWG. However, seed yield was substantially lower than the earlier studies we have conducted at the KBS site (Culman et al., 2012; Tinsley, 2012). Temperature and population density may help explain the low seed yield observed in this study, but more research on agronomic optimized management is clearly needed. The genetic germplasm for IWG continues to improve as it is being selected for seed in addition to forage use; however, agronomic research will also require investment.



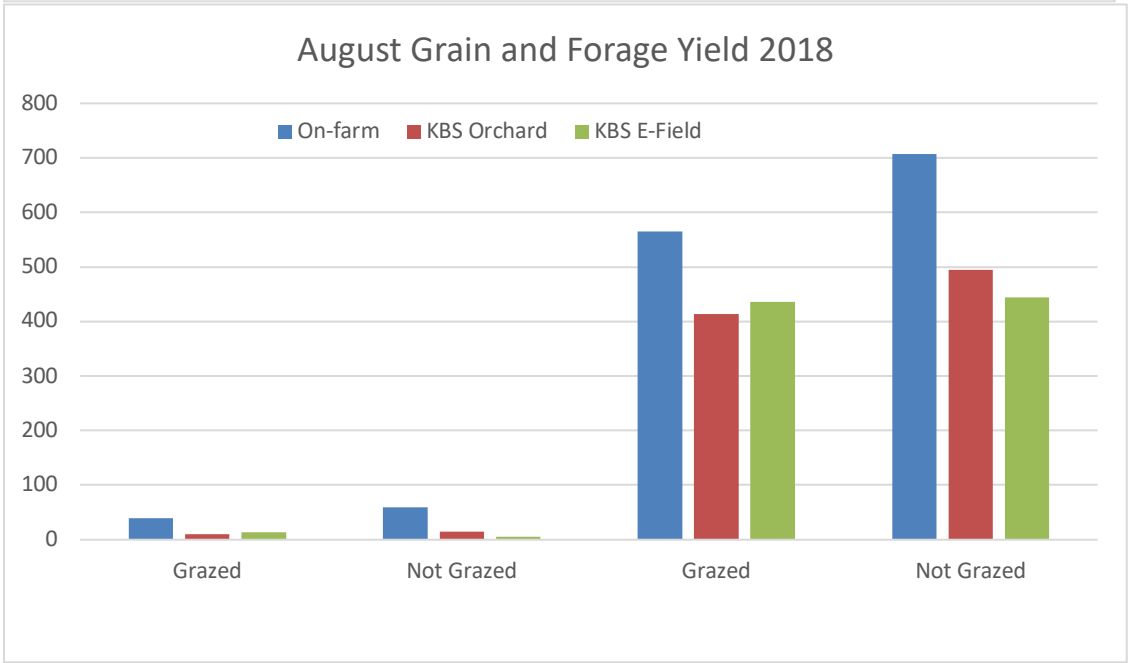


Figure 12. The August seed and forage yield harvested at three sites in Michigan is shown for 2017 (A) and for 2018 (B). No effect of grazing was observed in either year ($p>0.05$).

Forage quality evaluation was conducted on 2018 samples, and neutral detergent fiber was consistently higher in the grazed treatment (51.7) relative to the not grazed control (55.1). No difference was observed in other forage quality properties analyzed by NIR, such as acid detergent fiber or crude protein (15.9 vs 14.5%). This is a preliminary but promising finding, that forage yield is not reduced by grazing whereas forage quality may be higher under grazing.

Overview and Future research needs

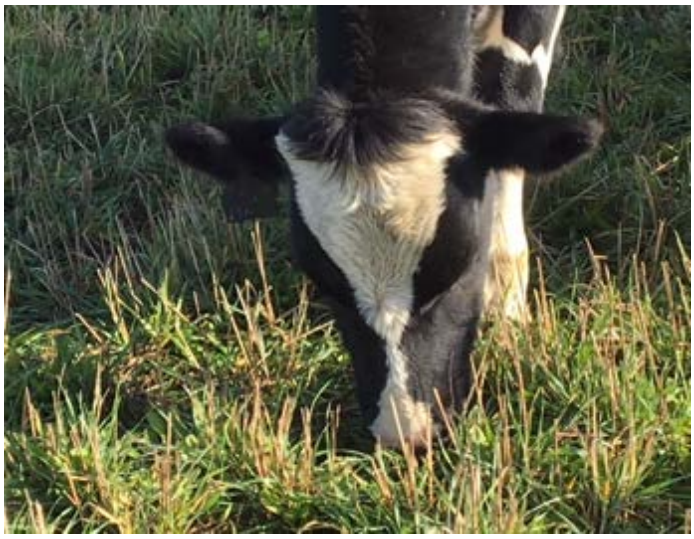
The intermediate wheatgrass is a valuable crop for its ecological contributions, with its deep rooting system serving to hold soil and greatly reduce nutrient leaching. The value for production has yet to be realized since sound agronomic practices have yet to be identified. Many farmers seek seed but the challenge is to establish the crop as a perennial and manage weeds. This is especially true in organic systems.

Intermediate wheatgrass two weeks before harvest at KBS, (August 11, 2017. (Photo by Vicki Morrone)

Harvest of intermediate wheatgrass at Hampshire Farms. September 7, 2017 (photo by Shirley Hampshire)

Randy Hampshire presenting at the Field day on his farm. (October 30, 2017)

Field day participant (Andrea Weiss) enjoying the Jerseys at Hampshire Farms day 1 of grazing of the Intermediate wheatgrass pasture (Oct 30, 2017).



Holstein at KBS choosing the best of the intermediate wheatgrass at KBS (Nov 3, 2017)

Vicki Morrone presenting findings to group during KBS field day (photo by Sieg Snapp)

Joe Scrimger, Bio-Systems-Mid Michigan finds takes interest in the opportunities that IWG affords for dairy farmers and the environment.s

The research at these sites will continue through the end of 2019. We anticipate increased biomass and grain yield, and look forward to a third year of field days in Michigan.

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