Comparing the Caloric Outputs of Intermediate Wheatgrass, Wheat, and Corn

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1 Introduction

Over half of the world's agricultural land is currently dedicated to annual grain crops. (Monfreda et al., 2008) These annual grain crops have undergonedomestication for thousands of years and are highly productive, but unfortunately there are negative consequences associated with growing these grains. A major concern related to common annual grain crops such as wheat and corn is their impact on the climate is the leaching of nitrogen which can contaminate groundwater. High levels of nitrate contamination harms both the environment and public health (Ward, 2018). IWG also been shown to reduce nitrate leaching by 99% when compared to corn (Jungers, 2019).

Today, many researchers are focusing on perennial crops to potentially reduce these consequences. Intermediate Wheatgrass is the only perennial grain crop with the potential to replace these traditional crops that is far enough along in it's development to be considered economically and commercially viable. IWG has the potential to provide a number of environmental benefits over annual grains such as corn and wheat, including improved soil quality, decreased erosion, and carbon sequestration (DeHann, 2017).

The Land Institute (an agricultural research facility in Kansas) began developing IWG in 2003. It was registered under the trademark of Kernza® in 2011 and the commercialization plan began. Chipotle Mexican Grill began trials to incorporate IWG into their tortillas around this time and the first farm field of IWG was established, proving this crop's agronomic viability. In the following years, more companies began to show interest in using Kernza®in their products, including General Mills, who began Kernza® R&D in 2016 and launched their cascadian farms Kernza® cereal in 2018.

Grain yields of IWG are very low compared to conventional grains, averaging around 400-900 lbs of grain per acre per year, which is only around 20% of the yield of spring wheat in Minnesota (Vocke, 2013). Fortunately, IWG has a dual-use potential, meaning that the crop produces both grain that can be eaten by humans and forage that can be fed to dairy cows to produce milk. IWG is typically harvested in the summer, and at this point the crop can be harvested for both grain and straw which can be eaten by cows. IWG can also be harvested in the spring and fall. These spring and fall harvests include only forage (hay) and do not produce grain. Both one cut IWG system (straw only) and a three cut IWG system (hay and straw) were evaluated in this study. This study evaluated the question of whether the forage output of IWG can compensate for low grain yield when compared to conventional annual-based cropping systems in terms of land use. The differences in the caloric production output of four different systems: corn, wheat, IWG harvested for hay and straw, and IWG only harvested for straw were evaluated.

2 Methods

2.1 Overview of Data Analysis

To compare the net caloric and protein value of the various crops included in this study, grain and biomass yields (kg/hectare) were converted into calories consumable by humans in food products produced by each crop (e.g., grain and milk). This approach accounts for different conversion efficiencies of converting raw agricultural products to human caloric output. For example, a significant percentage of the corn grown in the US is used as livestock feed for meat production. Silage corn is also grown fed to dairy cows, to produce milk that is directly consumed by humans. Therefore, some of the energy from the corn is lost during the conversion of energy from the corn to milk. IWG is unique because it produces biomass that can be used to generate multiple forms of food energy for humans: grain which can be eaten directly and forage that can be used as livestock feed to produce milk. Since IWG is a relatively new crop, publically available data on yields are limited. Data from multiple research experiments on IWG spanning 5 years and 4 locations was used. Yield data on wheat and corn was sourced from the USDA NASS. Conversion coefficients published in the literature and used by commercial laboratories were used to estimate caloric and protein outcomes of all crops.

2.2 Data Collection

The data used in this analysis include a combination of empirical data from field trials and from national databases. All data regarding Intermediate Wheatgrass yield and economics were collected from eight experiments conducted by the Sustainable Cropping Systems Laboratory at the University of Minnesota. These experiments took place between the years of 2015 and 2022 at research sites throughout the state of minnesota. These data were used to calculate the average yield and relative forage quality (RFQ) IWG. The National Agricultural Statistics Service (NASS) (A subsidiary of the USDA) provided all yield data related to wheat, corn grain, and corn silage. The Dairy One Forage Laboratory's Feed Composition Library provides a variety of data on all common forages. For this study, the value of milk per ton of forage was pulled from the Dairy One Dataset. The USDA's Agricultural Utilization Research Institute published a nutritional comparison of Intermediate Wheatgrass and Wheat grain that was used to gather all caloric and protein values per gram. The number of calories as well as protein per gram for milk was calculated using the nutrition facts provided for whole milk (3.5% milk fat) from the USDA's Food Data Central.

2.3 Yield Comparison

IWG average yields were calculated with data from the University of Minnesota SCS lab's data set. Excel was used to calculate an average over all of the experiments. The wheat yield average was determined from USDA NASS data. Excel was used to calculate the average over all five states (Minnesota, Michigan, Wisconsin, Indiana, and Iowa) over all five years (2018-2022) (average of all 25 data points). The yield was converted from $\frac{\text{bu}}{\text{acre}}$ to dry matter yield in $\frac{\text{kg}}{\text{ha}}$ using conversion factors in Table 1. The average yield for corn was determined in a similar way. Silage corn data was collected from the NASS, and an average of the 25 data points was calculated using Excel. This was converted into $\frac{kg}{ha}$ to match the SCS Data set.

Crop	Grain Yield Average $\frac{bu}{acre}$	Conversion Factor	Grain Yield $\frac{kg}{ha}$	Forage Yield Average $\frac{ton}{acre}$	Conversion Factor	Forage Yield Average $\frac{kg}{ha}$
Wheat	70.0	0.01487	4704.88	N/A	N/A	N/A
Corn	N/A	N/A	N/A	20.404	2242	45731
IWG (Straw Only)	6.31	0.01487	424.43	3.65	2242	8193
IWG (Hay+Straw)	4.93	0.01487	331.58	3.37	2242	7566

Table 1: Yield Comparisons and Conversion Factors

2.4 Food Energy Comparison $\frac{Gcal}{Ha}$

Conversion Factor	Value
Calories per gram of IWG	3.68
Gallons Milk per Kg Grass Hay	0.321
Gallons Milk Per Kg Grass Straw	0.180
Gallons Milk Per Kg Corn	0.452
Calories per Gallon Milk	2336

Table 2: Conversion Factors used to Calculate Caloric Outputs

In order to calculate the total food energy produced by IWG, the nutritional values from the USDA AURI ((Kernza® Perennial Grain as a Cereal Grain, n.d.) were used to calculate the caloric output of the grain. The milk output from the forage was calculated separately for hay and straw, using grass hay and straw values from the Dairy One database, respectively. The amount of milk was converted into calories, and the calories from the milk and grain were added together for total calories per hectare.

To find the total food energy produced by wheat, the nutritional values from the AURI report were used to calculate the caloric output per ha using simple multiplication.

To find this value for corn, the first step was to convert the forage output of corn into gallons of milk, using the milk/ton from the Dairy One Database. This was converted from lbs of milk/ton of forage to gallons of milk/kg of forage. Then, the gallons of milk were converted into calories using the USDA Food Data Central's nutrition facts for milk.

The calculation of caloric output for IWG from hay and straw is provided below as an example:

$$(Y_g * C) + (Y_H * G_H * C_M) + (Y_S + G_S)$$

Where:

Y_G is Grain Yield, kg ha^{-1}
C is Gcalories per kilogram of grain, kg ha^{-1}
Y_H is Hay Yield, kg ha^{-1}
G_H is Gallons of milk produced by given Hay Yield, kg ha^{-1}
C_M is Calories per gallon of milk produced, kg ha^{-1}
Y_S is Straw Yield, kg ha^{-1}
G_S is Gallons of milk produced by given straw yield, kg ha^{-1}

2.5 Protein Comparisons

To find the protein production of intermediate wheatgrass, the nutrition information from the AURI was used to calculate percent protein from the grain, and total protein (gcal/ha) was calculated using those statistics. This was added to the gcals of protein from the milk from the forage output of the wheatgrass to find total gcalories of protein per hectare.

A similar process was used for wheat, the nutrition information from AURI was used to calculate the percentage of calories from protein for this crop, which was multiplied by the total calories.

To find this value for corn, the Nutrition information from the USDA Food Data Central was used to find percentage of calories from protein for whole milk. The calculation of protein output for IWG harvested for hay and straw is provided below as an example:

Example 2:

$$(C_g * P_g) + (C_H * P_M) + (C_S * P_M)$$

Where:

C_g is Calories of IWG Grain per hectare, Gcal ha^{-1}
P_g is Percent calories from protein in IWG grain, %
C_H is Calories produced per hectare by Hay, Gcal ha^{-1}
C_S is Calories produced per hectare by Straw, Gcal ha^{-1}
P_M is Percent calories from protein in milk, %

3 Results

3.1 Yield Comparisons for Wheat, Corn, and Intermediate Wheatgrass

Crop	Grain Yield $\frac{kg}{ha}$
Wheat	4705
IWG (Straw Only)	424
IWG (Hay and Straw)	332

Table 3: Numerical Grain Yields $\frac{kg}{ha}$ for Wheat and Intermediate Wheatgrass

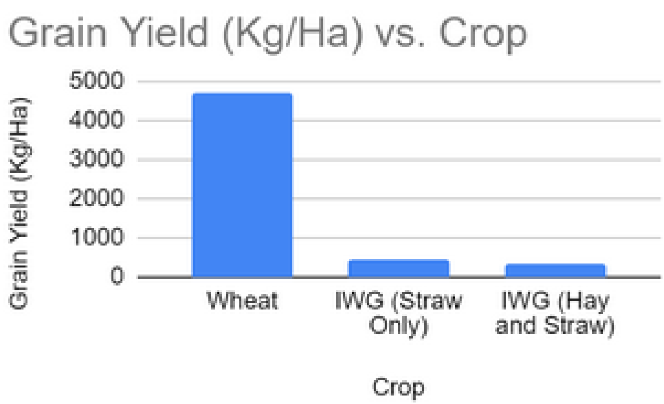

Figure 1: Comparison of Grain Yields $\frac{kg}{ha}$ for Wheat and Intermediate Wheatgrass

As shown by figure 1, Intermediate Wheatgrass was not competitive with wheat regarding grain yields.

Crop	Grain Yield $\frac{kg}{ha}$
Corn	16006
IWG (Straw Only)	8193
IWG (Hay and Straw)	7565

Table 4: Numerical Forage Yields $\frac{kg}{ha}$ for Corn and Intermediate Wheatgrass

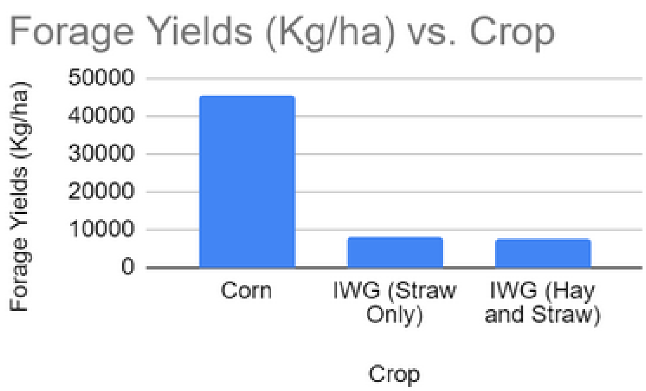

Figure 2: Comparison of Grain Yields $\frac{kg}{ha}$ for Corn and Intermediate Wheatgrass

As shown by figure 2, Intermediate Wheatgrass was not competitive with corn in regards to forage yield.

Crop	Caloric Output $\frac{\text{Gcal}}{\text{ha}}$
Wheat	12.9
Corn	16.9
IWG (Straw Only)	4.81
IWG (Hay and Straw)	4.97

Table 5: Numerical Caloric Output for Wheat, Corn, and Intermediate Wheatgrass

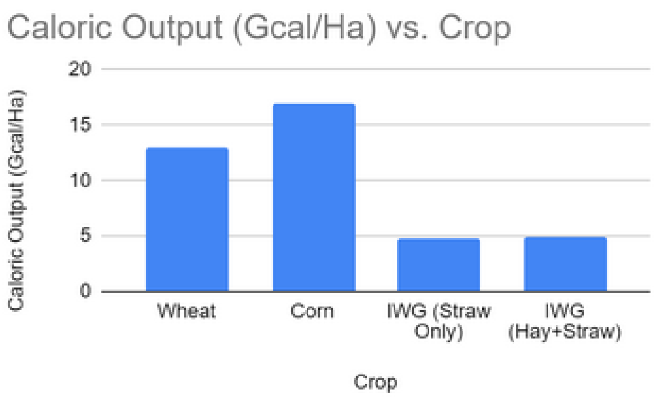

Figure 3: Comparison of Caloric Output for Wheat, Corn, and Intermediate Wheatgrass

While intermediate wheatgrass is more competitive in this category, caloric outputs remain only around a third that of wheat and a quarter that of corn.

Crop	Protein Output (Gcal/Ha)
Wheat	0.376
Corn	3.70
IWG (Straw Only)	0.827
IWG (Hay and Straw)	1.14

Table 6: Numerical Protein Output for Wheat, Corn, and Intermediate Wheatgrass

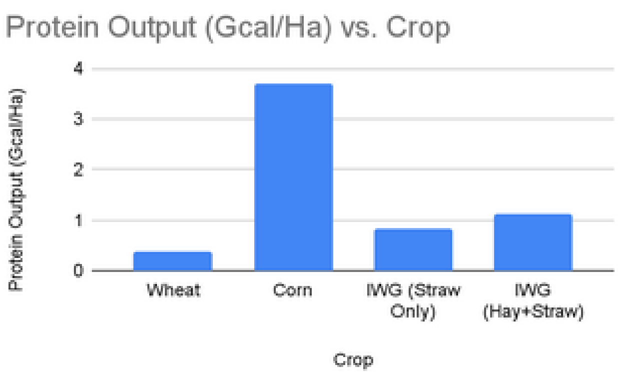

Figure 4: Comparison Protein Output for Wheat, Corn, and Intermediate Wheatgrass

Intermediate Wheatgrass outperformed wheat regarding protein output per acre. In fact, Wntermediate Wheatgrass that is cut in both the spring and fall, produces three times as many protein calories as wheat. However, corn remains the most efficient producer of protein of the crops studied.

4 Discussion

The final goal of agriculture produce energy for human consumption. We need to make sure that people have balanced diets that include proteins, carbohydrates, and fats. Of these, protein is the most difficult macronutrient to produce. Certain legume crops are well suited to meet protien production needs and these same crops would complement our current agricultural system. When considering global nutrition and sustinance, organizations think of calories, then protein, then other nutrients. Intermediate Wheatgrass should not be considered for use as a land efficient crop to globally provide caloric content for humans. However, IWG could be used tot provide humans with the protein;this is due to both the dual-use potential and the actual protein content of IWG. Since IWG remains early in development, it cannot produce competitive grain or forage yields when compared to conventional crops. Because of IWG's low yields, the caloric output of IWG is not competitive with conventional crops. Yields and therefore caloric output could be improved via research into breeding and management. For example, if the summer straw output could have forage quality more similar to the forage quality of the hay, the output of milk (and therefore calories) would be much improved.

Of these avenues for improvment, researchers have had the most success in increasing seed size. However, increased seed size is also associated with less protein per gram of grain, since increasing seed size tends to exclusively involve increasing the amount of low-protien starchy endosperm. Therefore, it is unclear if increasing grain yields of intermediate wheatgrass by increasing seed size will have an positive impact on the protein production of the grain. Future research could include further study into the relationship between seed size and protein density. That research could be extended include other measures of nutrient density as well.

There were several limitations of this study. The main limitation is that the results do not account for the amount of product lost to processing, however, it can be reasonably assumed that loss due to processing is reasonably similar across all the cropping systems reported on in this study. Another limitation is that the IWG yields used in this study are lower than many reported yields in the literature. This is likely due to the multiple drought years included in the time frame of data collection. A final limitation is that the land use required to house and milk the cows is not calculated. However, this is a very small amount of the total land used to raise dairy cattle.

5 Conclusions

This study measured the yields, caloric outputs, and protein outputs of various crops. The yields of Intermediate Wheatgrass were substantially lower than the conventional crops. The caloric outputs of the IWG were roughly 37% of that of wheat and 28% of that of corn. The protein output of IWG was actually higher than wheat, more than doubling the protein output of the conventional grain. However, the protein output is only 22% of that of corn. These results were true for both an IWG system that was cut once per year, and an IWG system that included the major harvest in the summer, as well as smaller forage harvests in the spring and fall.

6 References

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