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Sorghum for corn: Water in the age of climate change

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Abstract

This paper discusses corn and sorghum growth in the United States with regard to moisture utilization. Current climate change research predicts changing temperature and moisture cycles in geographic regions employed for agriculture. This research project investigates crop management practices that may reduce irrigation needs while maintaining a food supply necessary to feed a growing world population under these predicted changes. By comparing the response of yellow field corn to red grain sorghum, we hypothesize that sorghum yields will be less affected by predicted changes in rainfall events and thus require minimal additional irrigation. To test our hypothesis, we vary the timing of watering events for two different patches of corn and sorghum. We find that sorghum is the more drought resistant crop, making it more suited to fare with the predictions of climate change and in the fight for a more food secure world.

Introduction

In the United States, the major feed grains are corn, sorghum, barley, and oats. Corn accounts for over 95 percent of total feed grain production and use, making it the primary U.S. feed grain (USDA ERS, 2018). The United States is the world's largest corn producer, exporting between 10 and 20 percent of annual production (USDA ERS, 2018). Corn production utilizes over 90 million acres of land in the U.S. (USDA ERS, 2018). Corn also finds its way into virtually every type of processed product one can imagine, including starch, sweeteners, corn oil, beverage and industrial alcohol, and fuel ethanol (USDA ERS, 2018). An alternate crop that can replace corn on those 90 million acres is sorghum. Sorghum has similar feed properties to corn, and it has been noted the energy value of sorghum is between 90 - 100% the energy value of corn (Etuk et. al., 2012). It has also been noted that sorghum sweeteners can replace corn sweeteners currently used in the food and beverage industry (Pirgari, 2007). Due primarily to financial considerations, however, corn production far exceeds that of sorghum in the United States (Taylor, 2013). This is due to the fact that corn is heavily subsidized by the U.S. government, making the market price of corn cheaper than the cost of production (Fields, 2004). In other words, farmers are much more likely to be guaranteed to be paid for growing corn and other heavily subsidized commodities than other crops. This profitability translates into acres planted; to compare, only 6.04 million acres were used in 2018 for sorghum production (USDA ERS, 2018). However, the U.S. remains the world's top exporter of sorghum, with an estimated 73.6% of global exports in 2016 (U.S. Grains Council, 2017). The good news on this front is that the gap in profitability between the two crops is changing, and in some cases, actually favoring switching from corn to sorghum (Spiegel, 2015).

Climate change research reveals that rainfall patterns will increase in variability, creating the possibility for

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Figure 1: Silk stage (Photo credit Joy Youwakim)

more extreme weather events with droughts and famines on one extreme and floods and hurricanes on the other (Seager *et al*., 2007; Meehl *et al*., 2000; EPA, 2016). This more extreme variation in temperature and precipitation can prevent efficient crop growth. One evident example was the corn yield across the U.S. corn belt in 2010 and 2012, during which high nighttime temperatures contributed to smaller yields (EPA, 2016). In terms of monetary loss, Michigan forfeited $220 million in the cherry sales of 2012 due to premature budding caused by a warm winter (EPA, 2016). For farmers, this means a higher probability of losing their crops due to lack of ability to fund (as well as supply) supplemental irrigation or to protect against floods. Drier and hotter temperatures mean more consistently dry soil as well as inconsistent growth seasons. Extreme and unpredictable rainfall and wind events speak for themselves simply in terms of crop safety. Although some crops are resilient enough to come back after intense storms, this cannot be guaranteed.

The effects of climate change can already be seen today through invariable weather patterns across the world. Parts of the Northern Hemisphere have been experiencing a premature arrival of spring-like conditions, which have led to earlier dates of snowmelt and increased river flows. Consequently, summer and fall, the seasons with the highest water demand, are being affected by a reduced availability of freshwater. From 1900 to 2002, the Sahel region of Africa has been experiencing higher drought conditions (NASA, 2010). This has been proven according to the Palmer Drought Severity Index, which is a measure of soil moisture using precipitation measurements and rough estimates of changes in evaporation (NASA, 2010). Specifically, in the United States, most of corn and sorghum production occurs in the Great Plains region, and the irrigation depends on the Ogallala Aquifer, which is declining in water levels (Taylor, 2013).

By 2050, it is predicted that seventy percent of the world's population will live in urban areas, and although fertility rates are slowing in several countries, the global population is expected to reach 9.6 billion by 2050 and 11.2 billion by 2100 (United Nations, 2015). Also by 2050, feeding a planet of 9 billion people will require an estimated 50 percent increase in agricultural production and a 15 percent increase in water withdrawals (Khokhar, 2017). Over 70 percent of freshwater is used for agriculture in most regions of the world (Khokhar, 2017). This means we very quickly need to become efficient at

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Figure 2: Tasseling and heading out stage (Photo credit Joy Youwakim)

growing food with minimal resources such as water and arable land. In addition to enhancing water use efficiency of irrigation methods (Howell, 2001), it is essential to select crops that optimize the conversion of water into grain (Spiegel, 2015). The dual threats of precipitation and temperature changes make finding water efficient crops that can handle irregular irrigation imperative. The purpose of this research is to simulate climate change in a controlled, yet natural environment, and observe the effects on both corn and sorghum, ceteris paribus.

Methodology

Two rows of both yellow dent corn and Mennonite sorghum (milo) were planted in tandem with thirty inches of soil between the rows on April 19th, 2016 in Liberty Hill, Texas. Both rows contained an equal amount of both crops, as pictured below.

As the seeds germinated, they spent six weeks in the ground with no additional irrigation or covering. Fertilizer and pesticides were not utilized. On May 21st, the plants were covered with a black tarp to prevent external rainfall from penetrating the soil, and a drip liner was snaked around the plants in order to control irrigation.
In this study, the irrigation cycle is modeled by the following differential equation:

$$dY_{pot}/dF=-\lambda|F_{opt} -F| \ (F>=0),\ Y_{pot}(F_{opt})=Y_{max}$$

Here, Y_{pot} is the potential yield per plant, Y_{max} is the maximum yield per plant, F_{opt} is the optimal frequency (measured in weeks) of precipitation (using optimal amount of water), and F is the experiment frequency ($F=1=F_{opt}$ for our weekly watering, $F=2$ for our biweekly watering), and λ is a constant of proportionality. In our experimental case, $F>=F_{opt}$, thus:

$$dY_{pot}/dF=\lambda(F_{opt}-F) \ (F>=0),\ Y_{pot}(F_{opt})=Y_{max}$$

Solving yields

$$Y_{pot}=\lambda\ (FF_{opt}-1/2\ F^2)+C.$$

Solving for C;

$$Y_{pot}=\lambda\ (FF_{opt}-1/2\ F^2)+(Y_{max}-\lambda\ 1/2\ F^2_{opt}).$$

Assuming $F_{opt}=1$(one week),then we have

$$Y_{pot}=\lambda(F-1/2\ F^2)+(Y_{max}-\lambda/2).$$

Using our data, we should be able to determine λ .

Table 1: Corn and Sorghum Yield and Growth based on Irrigation Variation

Final Total Yields	Corn	Sorghum
1 inch	2.435 lb.	.420 lb
2 inches	1.78 lb	.365 lb
Yield Decrease	27%	13%

Table 2: Corn Height by Irrigation Date

Irrigation Dates	Corn Heights
April 19th	0 feet
May 21st	3-4 ft
June 18th	6-7 ft
June 24th	10 ft

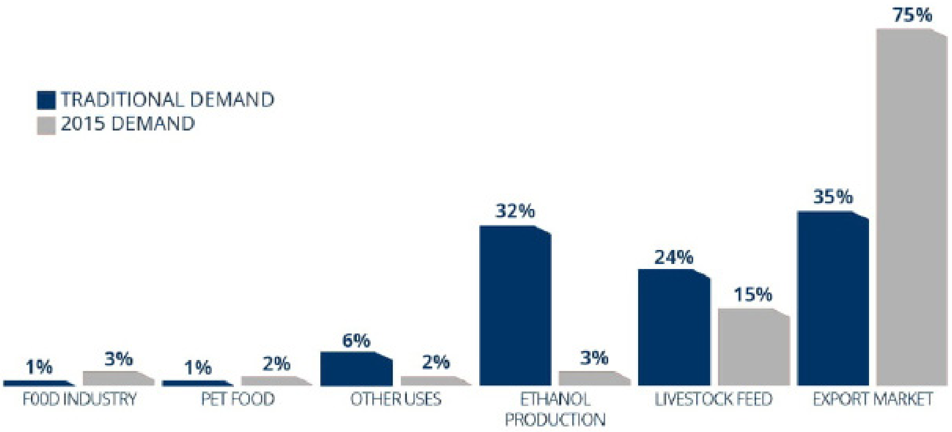

Figure 3: United Sorghum Checkoff Program 2015 Demand Comparison of Sorghum (Sorghum Markets Gain Momentum. (2016, May 02) Retrieved from http://www.sorghumcheckoff.com/news-and-media/newsroom/2016/05/02/markets-gain-momentum/ (15.09.2018)

This mathematical model implies that the change in yield potential for a plant is proportional to the difference between optimal frequency of watering events (rainfall, irrigation) and the actual frequency of watering events. The parameter lambda depends on the crop. A large value of lambda is indicative of crops where a small change in watering event frequency has a large effect on plant yield, whereas a small lambda would be indicative of a crop whose plant yield is fairly resistant to small changes in watering event frequency.

On June 11th, we began irrigating the first row weekly for one hour per week (at one time) in order to give it approximately an inch of water. The second row was watered bi-monthly (every two weeks), but received the same amount of water, two inches in a time span of two hours in one sitting. In the silk stage, which occurs about eight weeks after crop inception, we observed near equivalent height of both the climate change and control rows. In the tasseling and heading out stage the height difference was more clearly apparent, with a visible difference of about 6 inches of advantage to the control group. Pictured below are the silk stage on the left (Photo 1) and tasseling and heading out stage on the right (Photo 2).

Results

On July 30th, we were able to harvest both our corn and sorghum. We randomly harvested seven cobs of corn from each of the rows, and seven heads of sorghum from each row. The weekly irrigated corn weight amounted to 2.435 pounds, whereas the bi-monthly corn amounted to 1.78 pounds. The weekly irrigated sorghum weight amounted to .420 pounds, and the bi-monthly sorghum amounted to .365 pounds. These numbers portrayed a 13% yield decrease for sorghum, and a more substantial 27% decrease in corn yield. These findings reveal that sorghum is more suited to fare with the anticipated agricultural effects of climate change than corn.

Using these data, we can estimate lambda from the mathematical equation given above.

Corn:
Sorghum:

$1.78/7 = \lambda(2-1/2\cdot 4)+(2.435/7-\lambda/2)$
$.365/7 = \lambda(2-1/2\cdot 4)+(.420/7-\lambda/2)$

The resulting lambda for corn is .187 while the resulting lambda for sorghum is .016, demonstrating the larger discrepancy in corn yield loss due to changes in watering event frequency.

Conclusion

Sorghum is fungible to corn in terms of usage. It has benefits for livestock feed and its uses are largely diverse, ranging from ethanol to being used as a sweetener. The advantage of using sorghum for ethanol is that it produces the same amount of product per bushel, while using one- third less water than its counterpart (National Sorghum Producers, 2016). Furthermore, as proven by this research, sorghum fares better under moisture variability, which means less loss of crops and resources for farmers.

The U.S. errs on the side of low sorghum production for food due to the large amount of federal corn subsidies. U.S. crop subsidies for corn summed approximately $90 billion between 1995 and 2010, still excluding ethanol subsidies and mandates, which assisted in the increase of the price of corn (Foley, 2013). This also explains the choice to use sorghum more in ethanol production and the export market than in the food industry.

Concerning economic and environmental measures, choosing to grow corn in place of sorghum simply does not make sense. U.S. corn consumes an estimated 5.6 cubic miles per year of irrigation water withdrawn from America's rivers and aquifers (Foley, 2013). Choosing to grow more sorghum in place of corn will save on both costs and environmental damage due to water usage. One reason sorghum is not grown in place of corn is for fear of lack of marketable quality. For example, there's no "sorghum on the cob" recipe on Food Network. It is a food crop with popularity in Eastern hemisphere countries, such as Egypt and Ethiopia, where it is used to make breads (injera), cereals, and molasses. However, sorghum can be popped, used in salads, and even in some alcoholic drinks due to its sweetening capabilities. Once the gateway to sorghum flour is open, there is nothing to stop one from making delicious, gluten-free sorghum cookies, muffins, and pancakes. The options with this crop are endless, making it possible to be subsidized in the same way that corn is in the U.S., if not more so.

Corn's depletion of water resources is unsustainable for future resource allocation (Foley, 2013). This research shows that it would be prudent to grow sorghum in place of corn for the simple reason that the effects of variability of rainfall will be much less severe for sorghum than for corn (i.e. the comparison of lambda values). The quantitative value of growing a crop that can endure the same predicted weather conditions of the foreseeable future and have minimal yield loss are immense, especially in the United States due to our reliance on corn for livestock feed and its versatile nature as a sweetener (high fructose corn syrup, etc.). If we must rely on a grain to use in so many diverse roles, it should at least be one that conserves water.

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Conflict of Interests

The authors hereby declare that there is no conflict of interests.

References

United States Environmental Protection Agency. (2016, October 06). Climate impacts on agriculture and food supply. Retrieved from *https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-agriculture-and-food-supply_.html*

Fields, S. (2004). The fact of the land: Do agricultural subsidies foster poor health? *Environmental Health Perspectives*, 112(14), A820–A823.

Foley, J. (2013, March 5). It's time to rethink America's corn system. Retrieved from *http://www.scientificamerican.com/article/time-to-rethink-corn/*

Etuk, Edeheudim & Ifeduba, A.V. & Okata, U.E. & Chiaka, I & Ifeanyi Charles, Okoli & Okeudo, N.J. & Esonu, B.O. & Udedibie, A.B.I. & Moreki, John. (2012). Nutrient composition and feeding value of sorghum for livestock and poultry. *J Anim Sci Adv*.. 2, 510-524.

Khokhar, T. (2017, March 21). Chart: Globally, 70% of freshwater is used for agriculture. Retrieved from *https://blogs.worldbank.org/opendata/chart-globally-70-freshwater-used-agriculture*

National Sorghum Producers. (n.d.). National Sorghum Producers. Retrieved September 11, 2018, from *https://sorghumgrowers.com/sorghum-101/*

PÎrgari, E. (2007). Sweet sorghum -sweetener for foods. Cercetări Agronomice în Moldova Anul XXXX, 3(131), 1-6. Retrieved from *http://www.uaiasi.ro/CERCET_AGROMOLD/CA3-07-06.pdf*

Seager, R., Ting, M., Held, I., Kushnir, Y., Lu, J., Vecchi, G., . . . Naik, N. (2007). Model projections of an imminent transition to a more arid climate in Southwestern North America. *Science*, 1181-1184.

Spiegel, B. (2016, March 20). Grain sorghum may be more profitable than corn in high plains. Retrieved from *https://www.agriculture.com/crops/other-crops/sorghum/grain-sghum-may-be-me-profitable-th-cn_153-ar51472*

U.S. Grains Council (2016). Sorghum Harvest Quality Report 2016/2017. Retrieved September 11, 2018, from *https://grains.org/wp-content/uploads/2018/01/201617SorghumHarvestQualityOnePager-FINAL.pdf*

Taylor, M., & Brix, M. (2013). Profitability of non-irrigated corn and grain sorghum under yield and price uncertainty. Southern Agricultural Economics Association, 1-13. Retrieved from *https://ageconsearch.umn.edu/bitstream/143071/1/selected paper_Taylor Brix.pdf*

USDA ERS (2018, May 15). Corn and other field grains. Retrieved from *https://www.ers.usda.gov/topics/crops/corn-and-other-feedgrains/background/*

NASA. (n.d.) (2010, October 01) The water cycle: Feature articles. Retrieved from *https://earthobservatory.nasa.gov/Features/Water/page3.php*

UN Department of Economic and Social Affairs. (2015, July 29). World population projected to reach 9.7 billion by 2050. Retrieved from *http://www.un.org/en/development/desa/news/population/2015-report.htm*