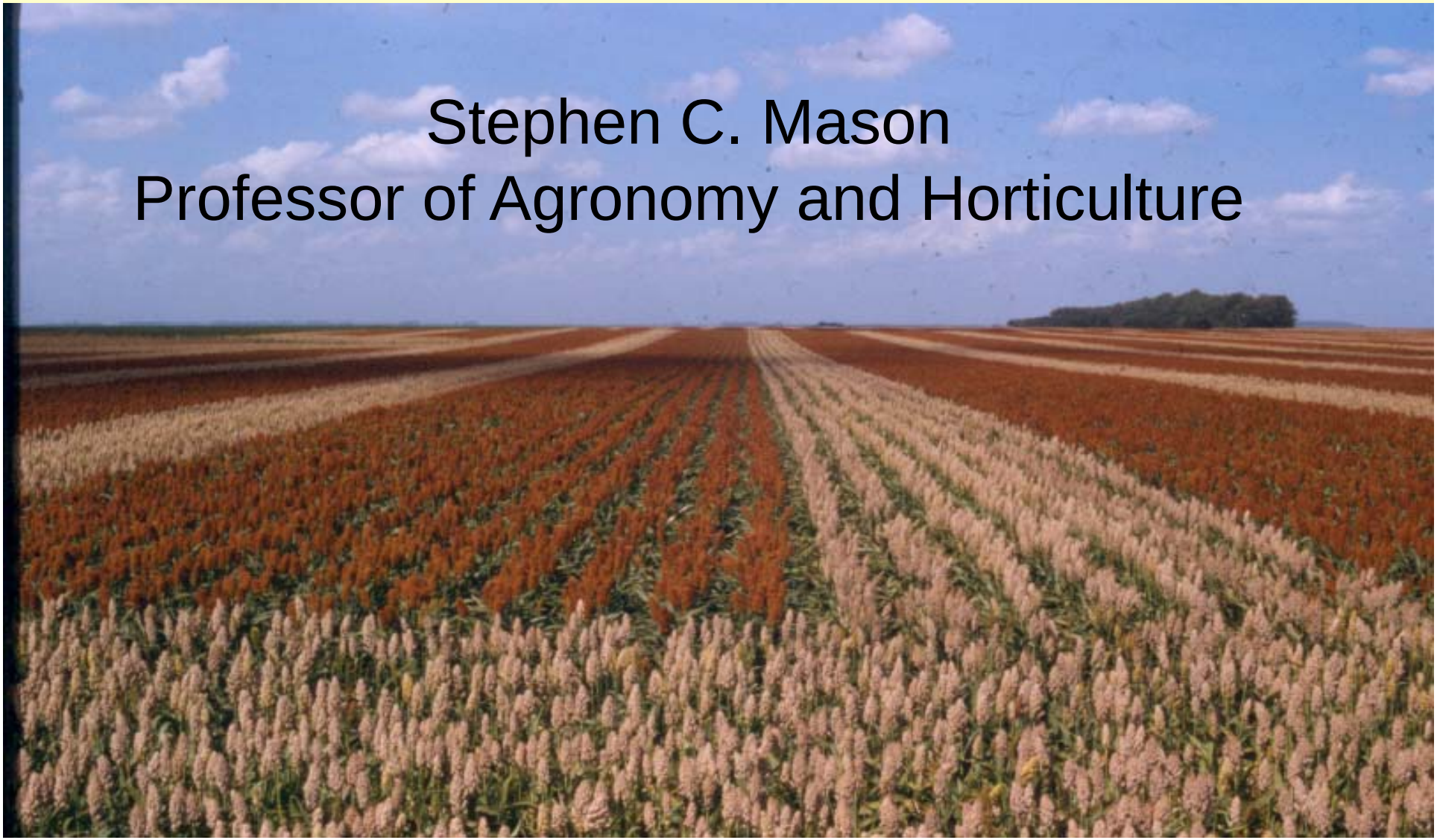
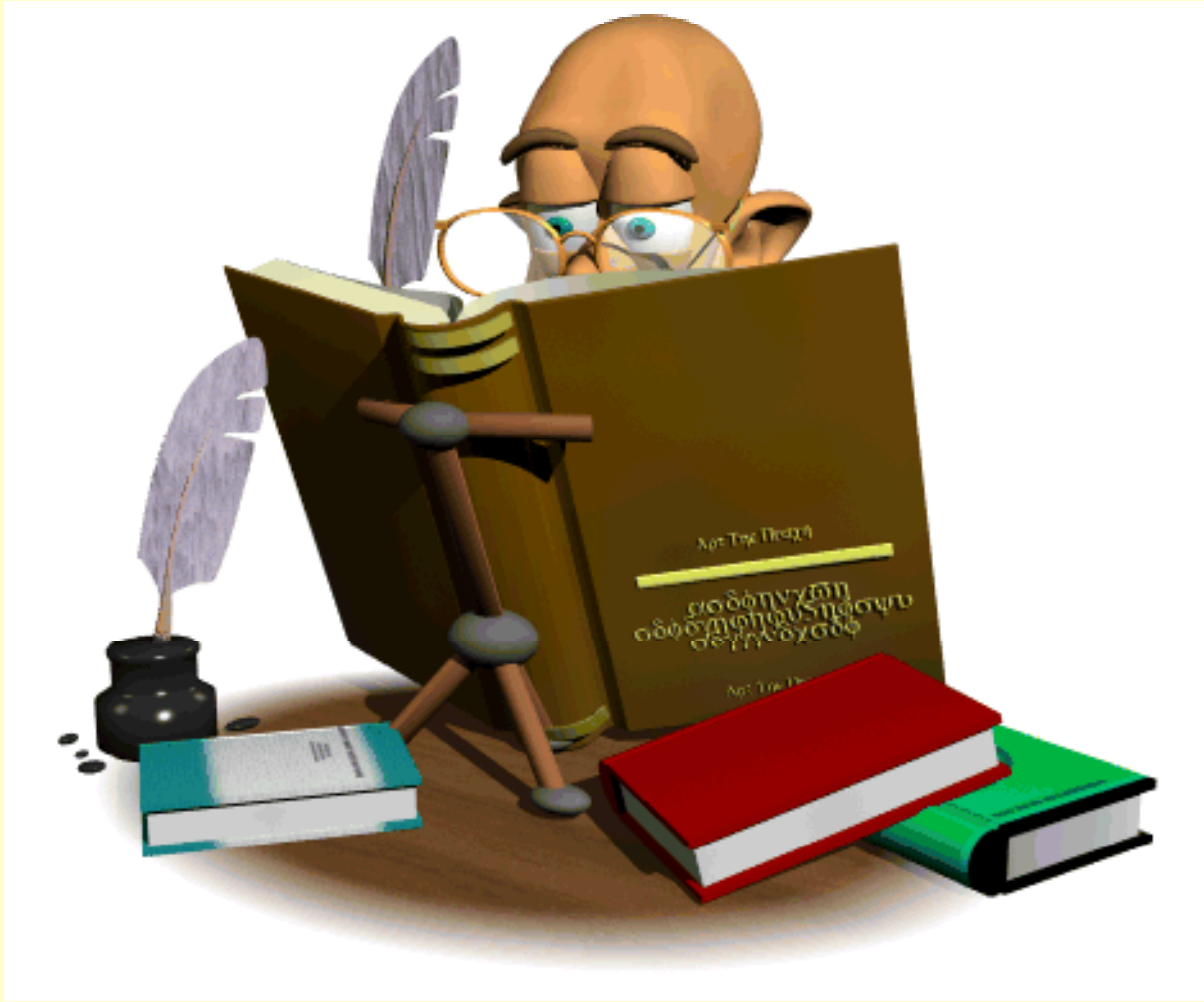
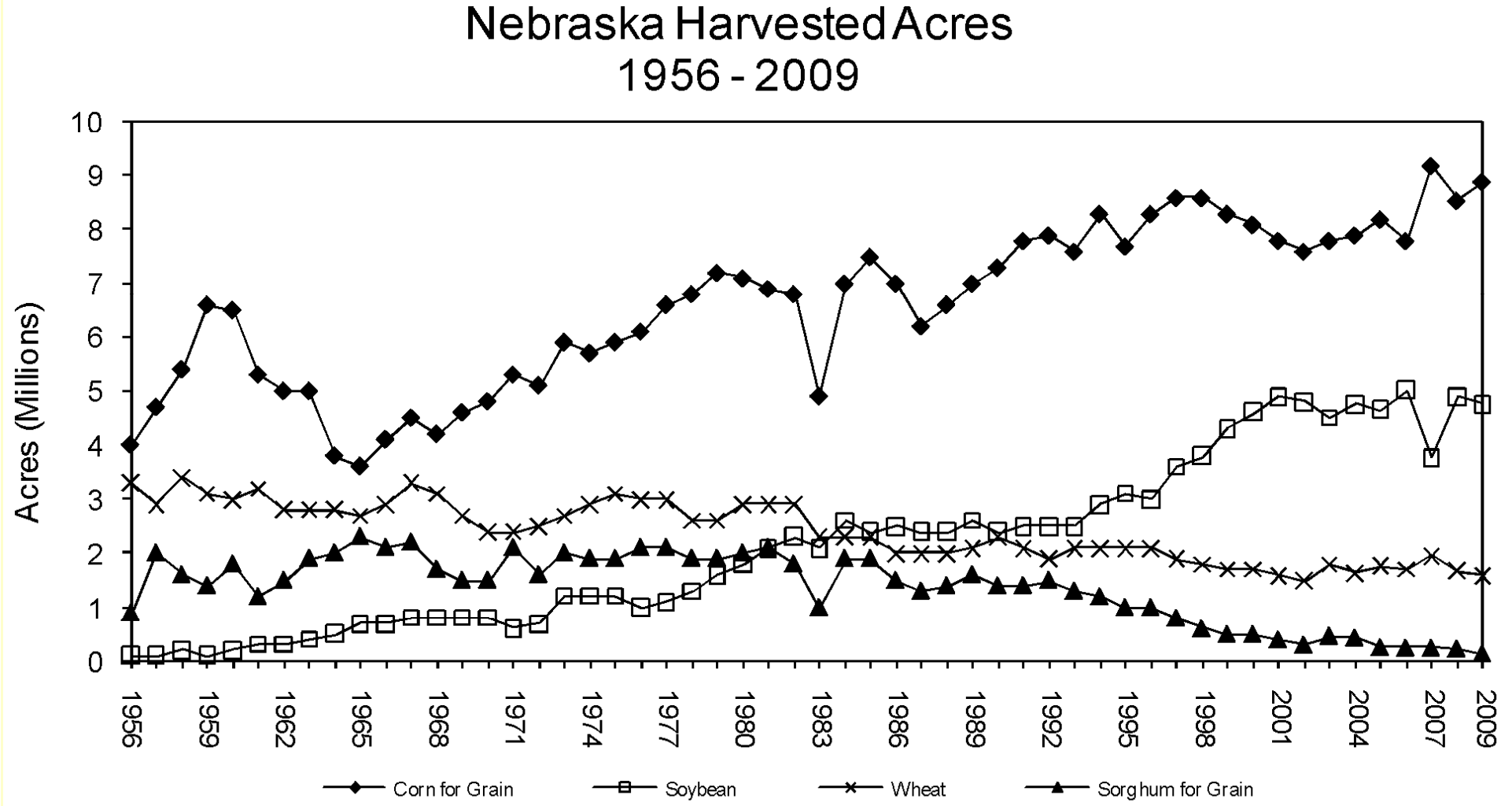
Grain Sorghum Opportunities for the Future



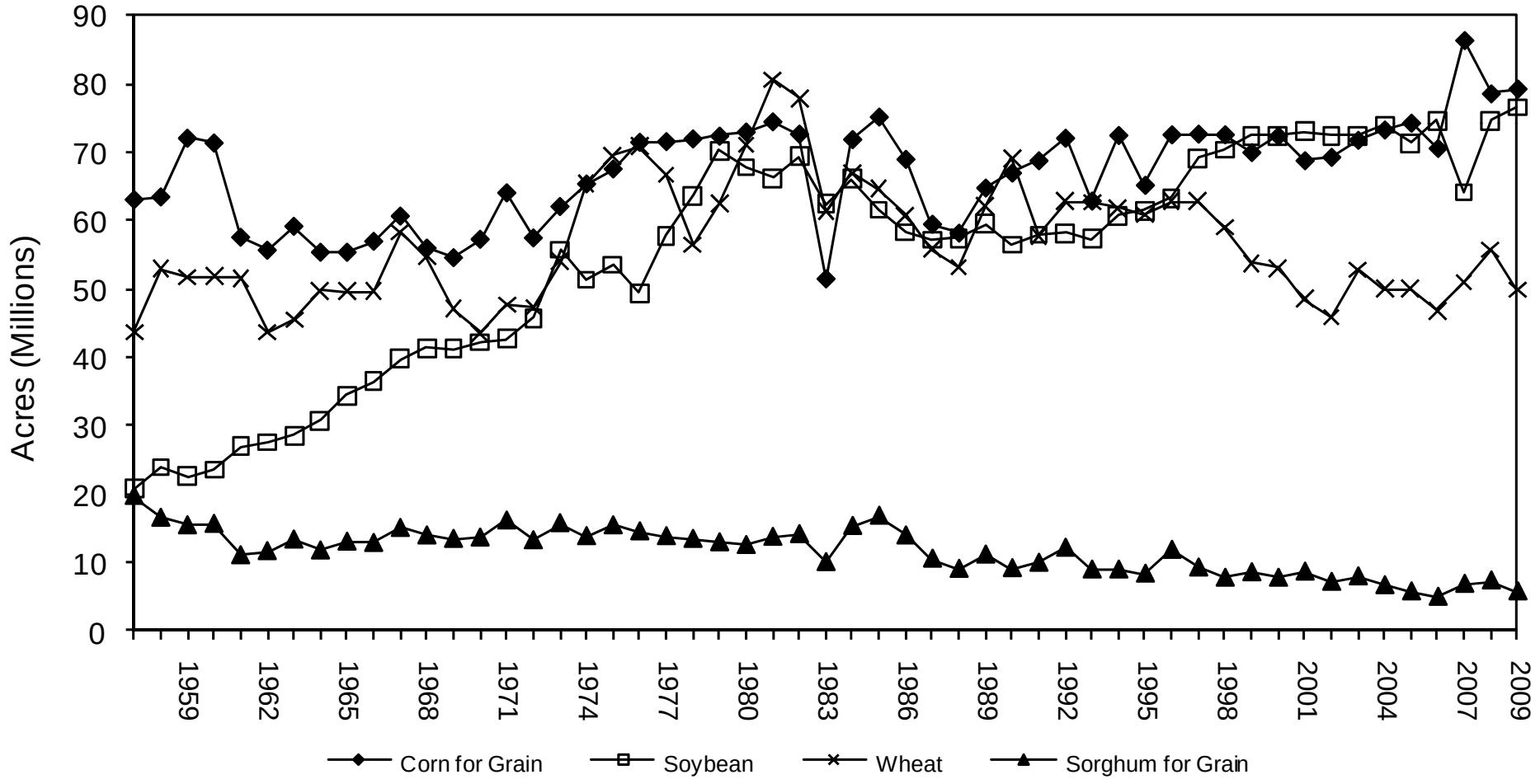
History - Past



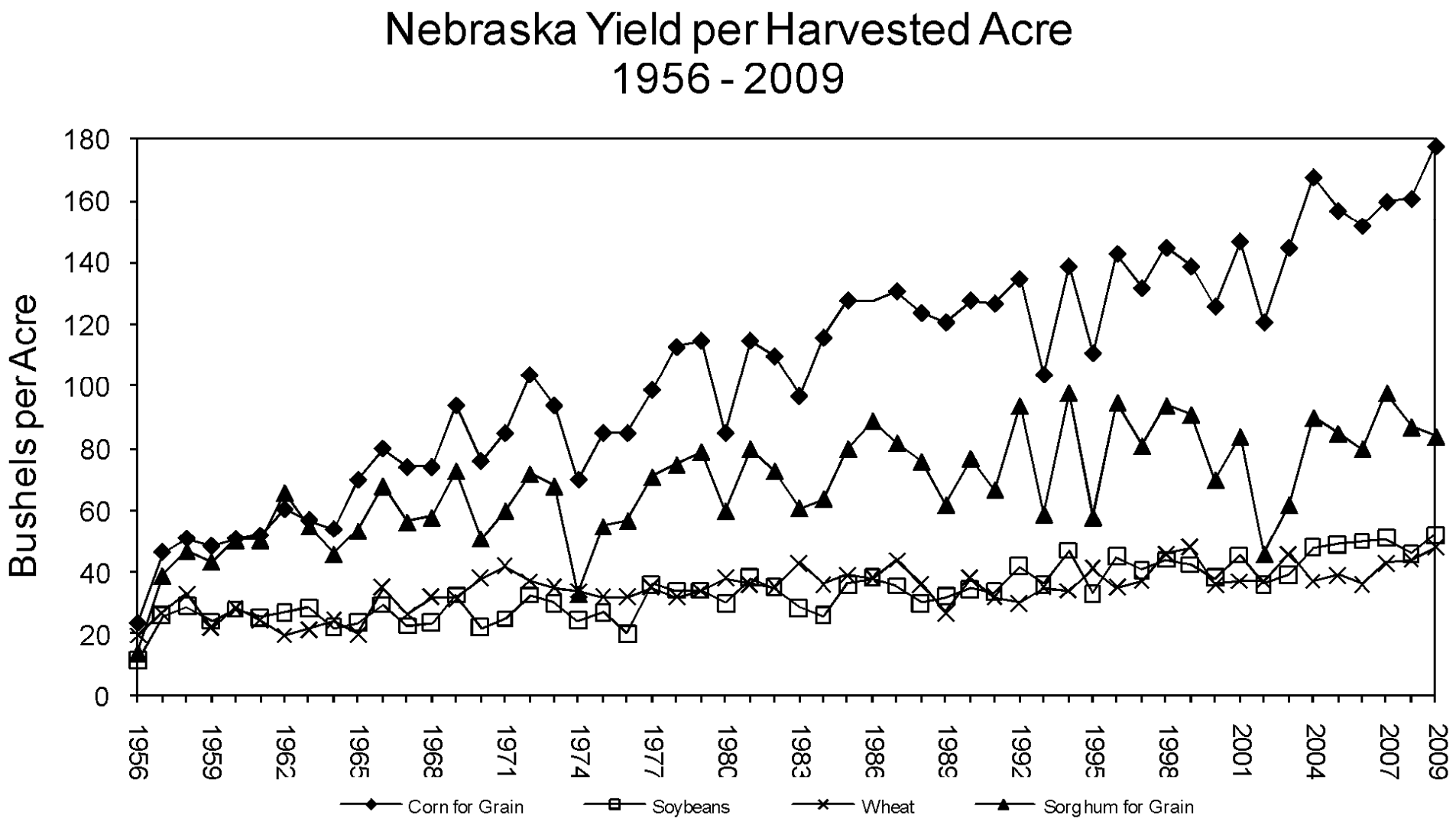
Nebraska Harvested Acres



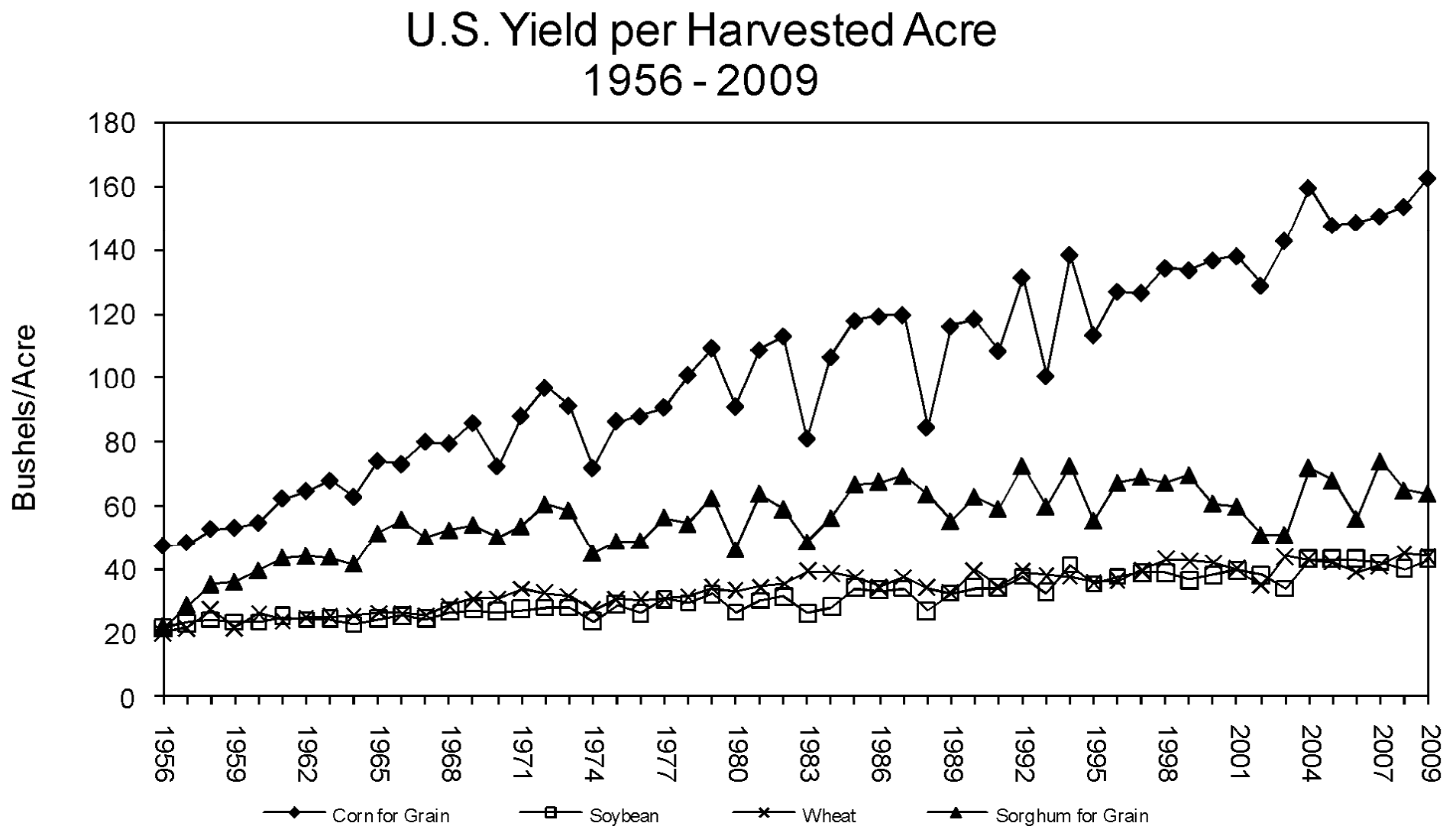
U.S. Harvested Acres



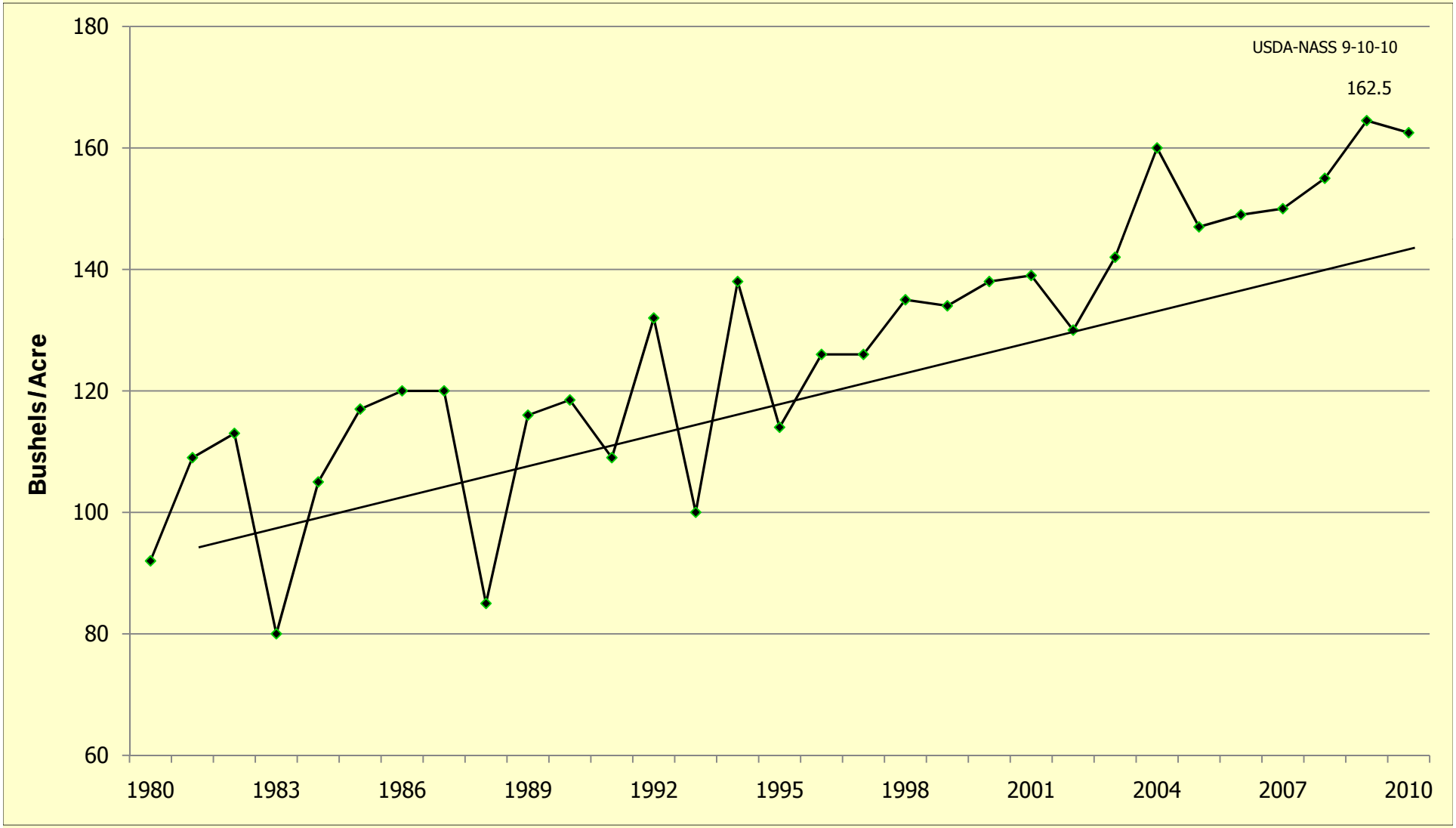
Nebraska Yield



U.S. Yield

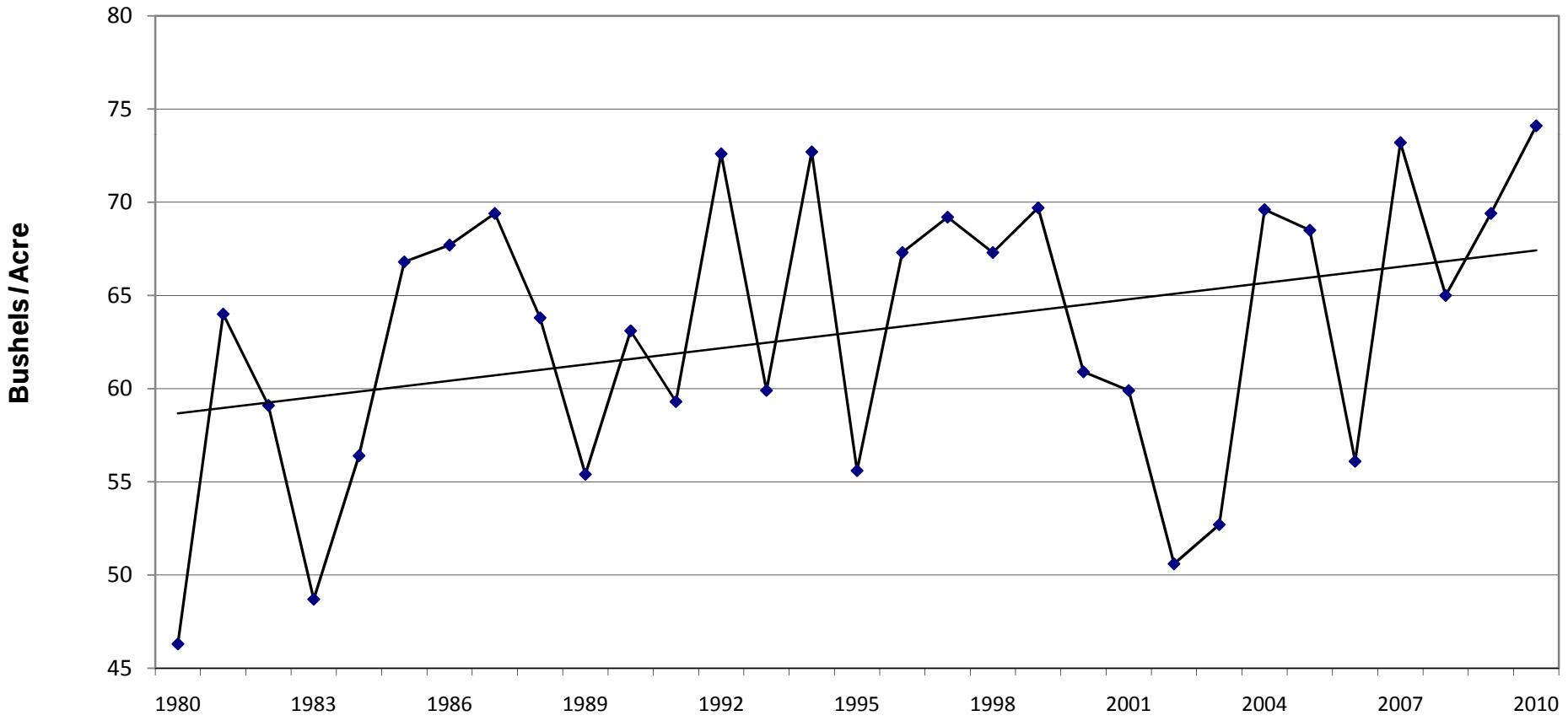

U.S. Yield per Harvested Acre
1956 - 2009
Bushels/Acre
180
160
140
120
100
80
60
40
20
0
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2009
Corn for Grain
Soybean
Wheat
Sorghum for Grain

U.S. Corn Yield



U.S. Grain Sorghum Yield

USDA-NASS
9-10-10

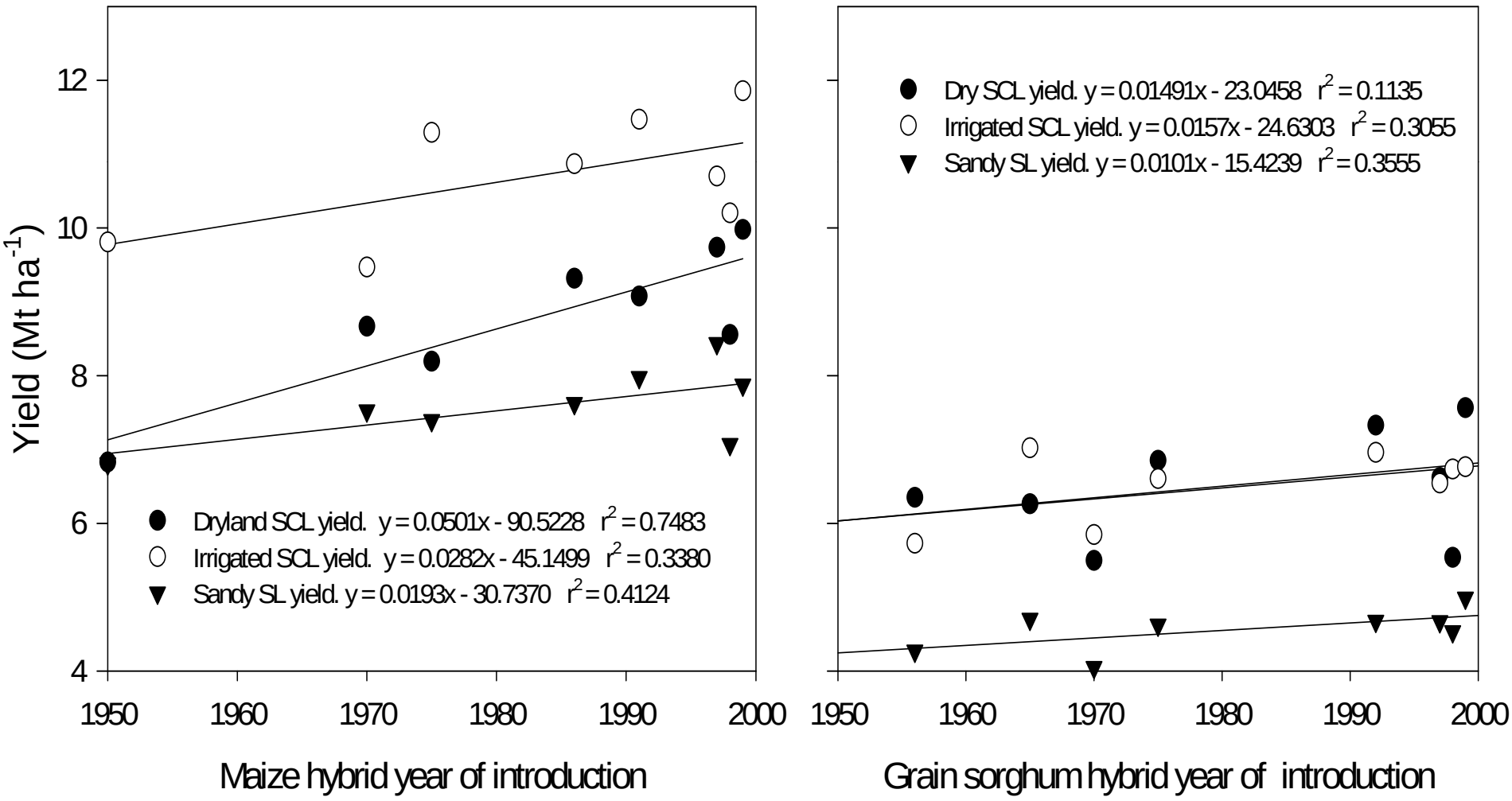


Factors Related to Dryland Grain Sorghum Yield Increases: 1939 through 1997

- 139% yield increase in Bushland, TX
- 46% due to improved sorghum hybrid
- 93% due to increased soil water present at planting (i.e. improved crop residue management practices)

[Agron. J. 91: 870 – 875]

Maize and sorghum yield in dryland sandy loam, dryland and irrigated silty clay loam soil by hybrid yr of introduction, Mead NE (Ave 3 yrs)



Why????

- Sorghum a risk aversion crop, thus yield is less responsive to breeding and management
- Sorghum is non-GMO due to potential for gene escape to weedy sorghum
- Tradition – farmer attitude
- Market opportunities
- The "itch factor"

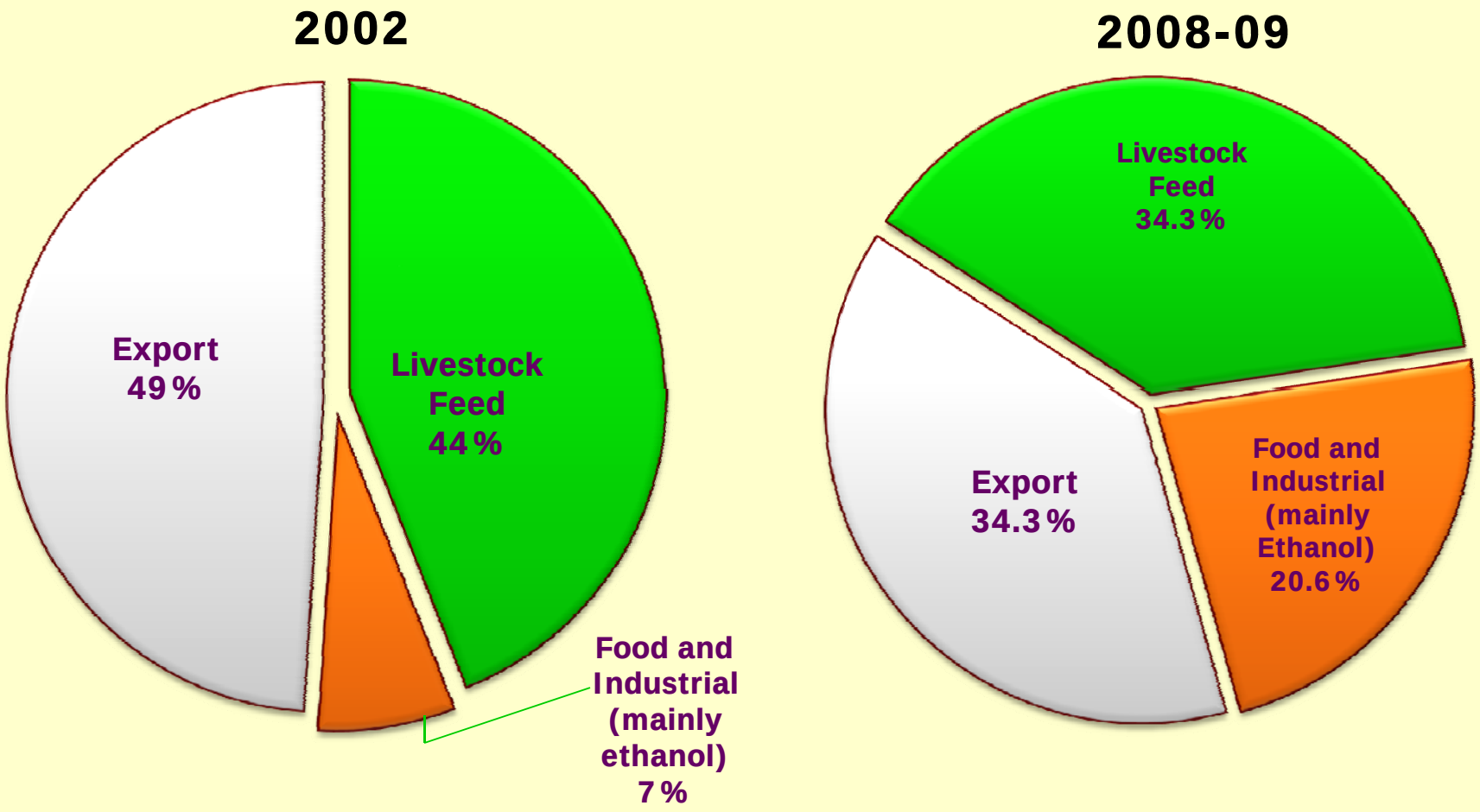
Research Investment

- Necessary to deal with problems and take advantage of the opportunities!
- Estimated number of plant breeders in the US
  - Maize =>500 plus many biotech support scientists
  - Sorghum =< 15 plus small biotech support

Annual research investment in the U.S.

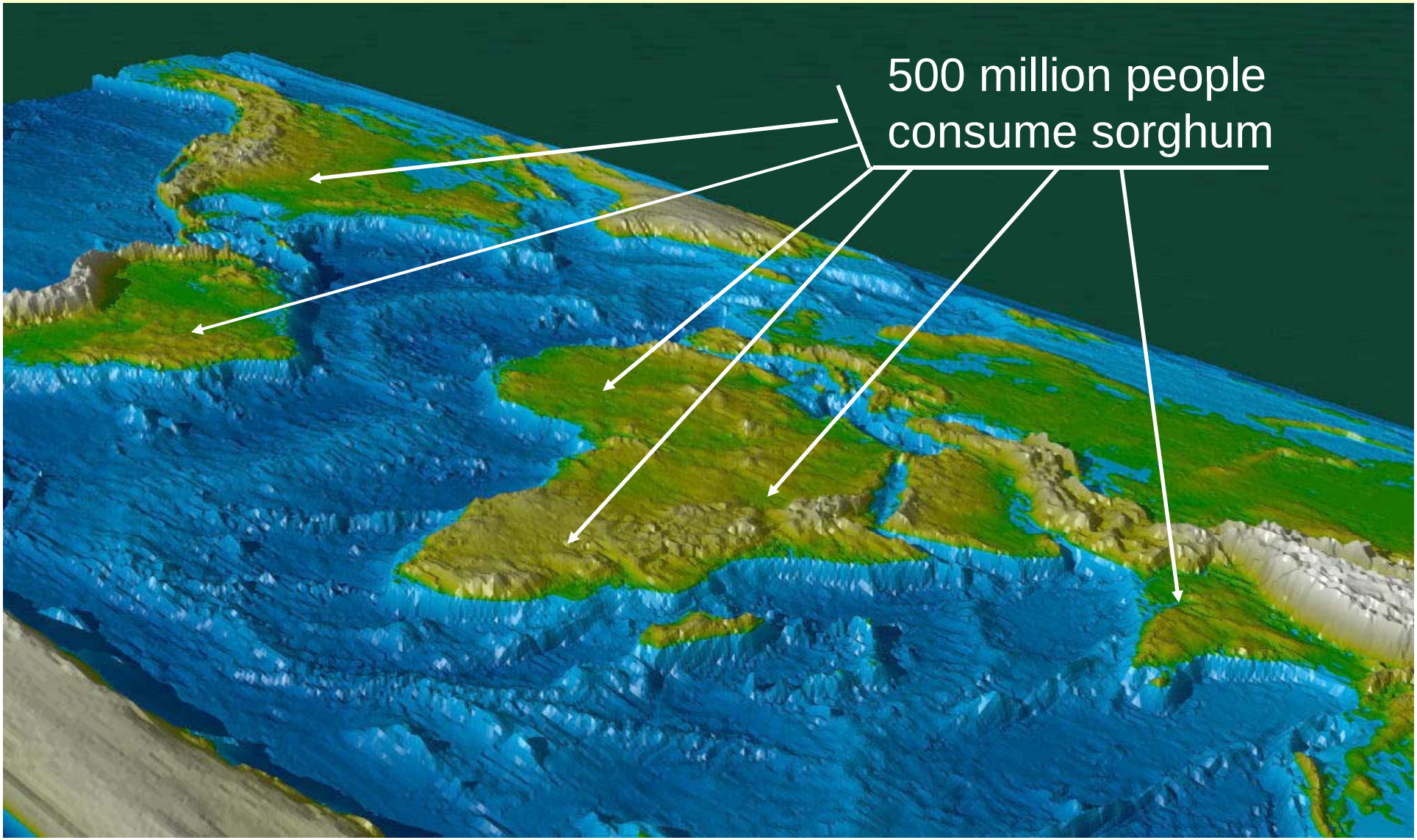
- Maize = estimated $1.1 billion
- Sorghum = estimated $10 million

Grain Sorghum Uses



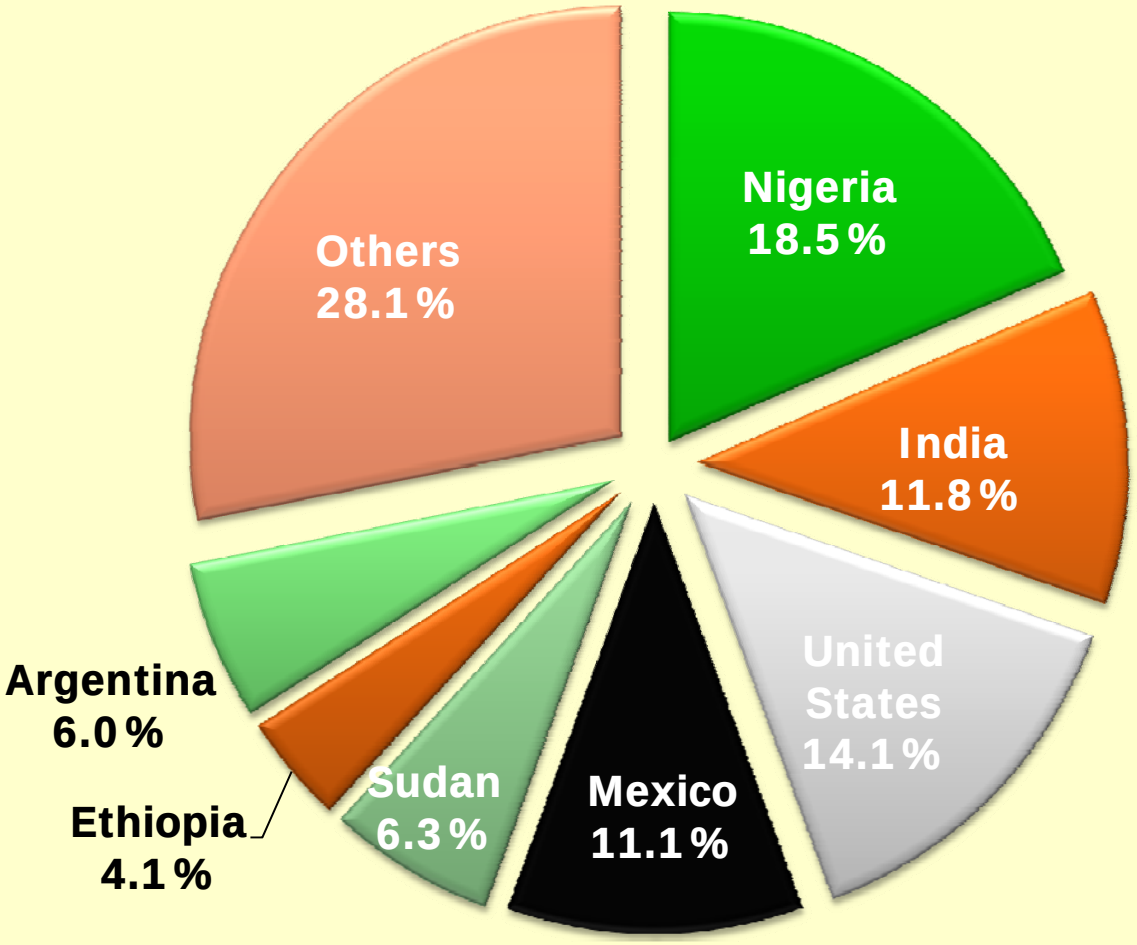
Present Situation

Sorghum Is a Major Crop Worldwide



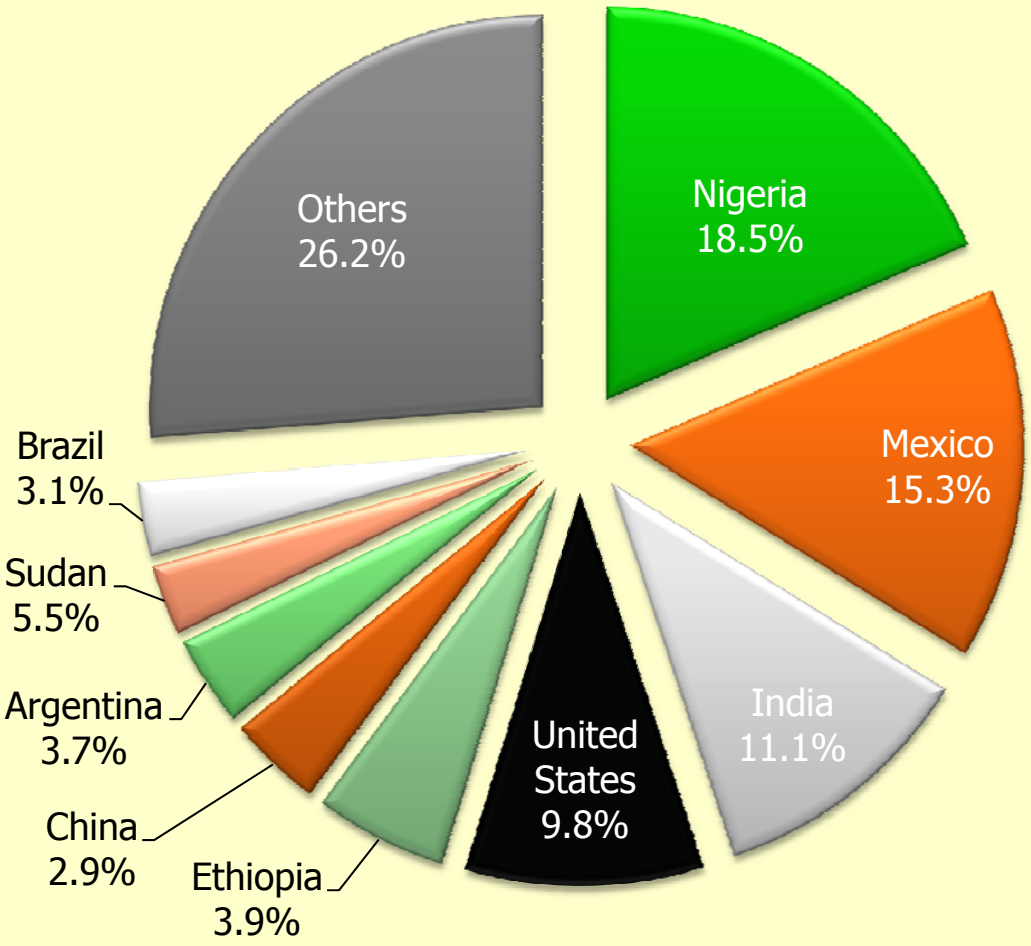
Grain Sorghum Major Producers

Major Producers	Millions Metric Tons
Nigeria	11.7
United States	8.9
India	7.3
Mexico	7.0
Sudan	4.0
Argentina	3.3
Ethiopia	2.6
Total	62.1



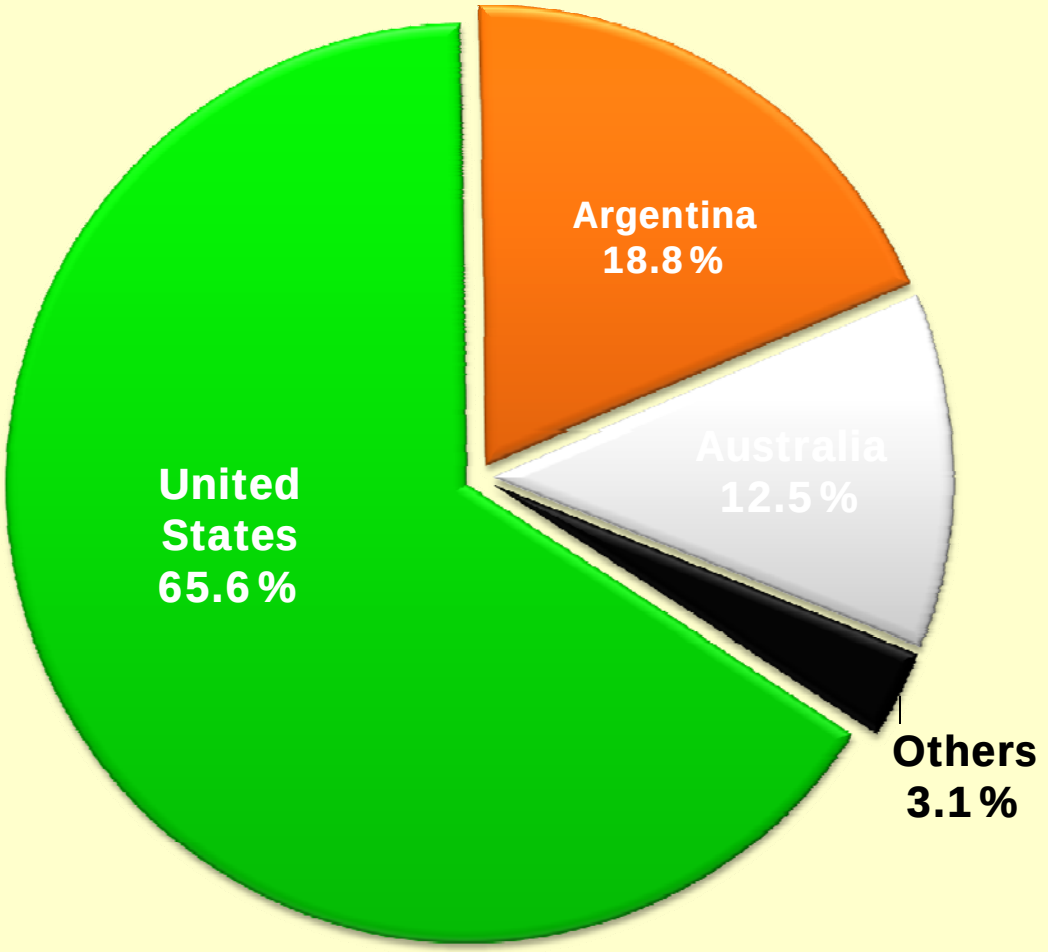
Grain Sorghum Major Consumers

Major Consumers	Millions Metric Tons
Nigeria	11.5
Mexico	9.5
India	6.9
United States	6.1
Sudan	3.4
Ethiopia	2.4
Argentina	2.3
Brazil	1.9
China	1.8
Other	16.3
Total	**62.1**



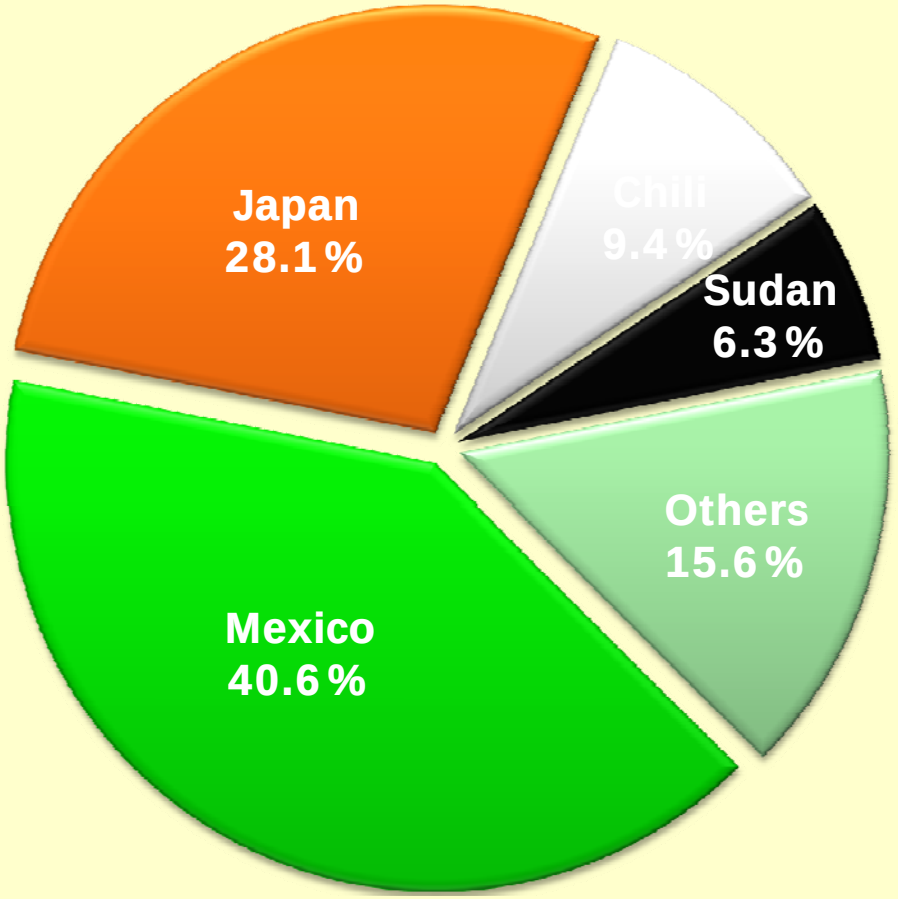
Grain Sorghum Major Exporters

Major Exporters	Millions Metric Tons
United States	4.2
Argentina	1.2
Australia	0.8
Others	0.2
Total	6.4



Grain Sorghum Major Importers

Major Importers	Millions Metric Tons
Mexico	2.6
Japan	1.8
Chile	0.6
Sudan	0.4
Others	1.0
Total	6.4



Nebraska- [2010](2009) 2008

Crop	Harvested Acres (million)	Yield (bu/acre)
Corn	[8.9](8.9) 8.55	[170](178) 163
Soybean	[5.1](4.75) 5.01	[55](52) 47
Wheat	[1.5](1.60) 1.67	[43](48) 44
Sorghum	[0.075](0.14) 0.22	[94](84) 87

United States- [2010](2009) 2008

Crop	Harvested Acres (million)	Yield (bu/acre)
Corn	[81.3](79.3) 78.6	[156](163) 154
Soybean	[76.8](76.6) 74.7	[44](43) 40
Wheat	[47.7](49.9) 55.7	[47](44) 45
Sorghum	[4.66](5.7) 7.3	[72](64) 65

% of U.S. Acres – [2010](2009) 2008

	% of U.S. Acres
Corn	[11](11) 11
Soybean	[6.6](6.2) 6.6
Wheat	[3.1](3.2) 3.0
Sorghum	[1.6](2.5) 3.0

Yield vs Profit
Lower Costs of Production

- Center Pivot Irrigated, No-Till Sorghum = $432.72 (160 bu/acre)
- Center Pivot Irrigated, No-Till Corn (Bt ECB & RW) = $640.01 (225 bu/acre)
- Center Pivot Irrigated, No-Till Corn (SmartStax) = $697.48 (225 bu/acre)

Conclusion

- Grain sorghum is an important crop worldwide, but has become a minor crop in NE
  - largely replaced by maize and soybean as major commodity crops
  - Small investment in research in both private and public sectors
  - Yield has increased more slowly for grain sorghum than for other crops
  - Modern maize hybrids and soybean varieties have increased stress tolerance, thus reducing this advantage of grain sorghum

Conclusion (Continued)

- Management is easier for corn and soybean than for sorghum – particularly weed control
- Grain sorghum has lower cost of production than corn
- Primary sorghum markets are more limited than for corn
  - Livestock feed (by relative feed value approximately 95% of maize)
    - Domestic
    - Export
  - Grain ethanol

Future Potential

As Commodity Crop???

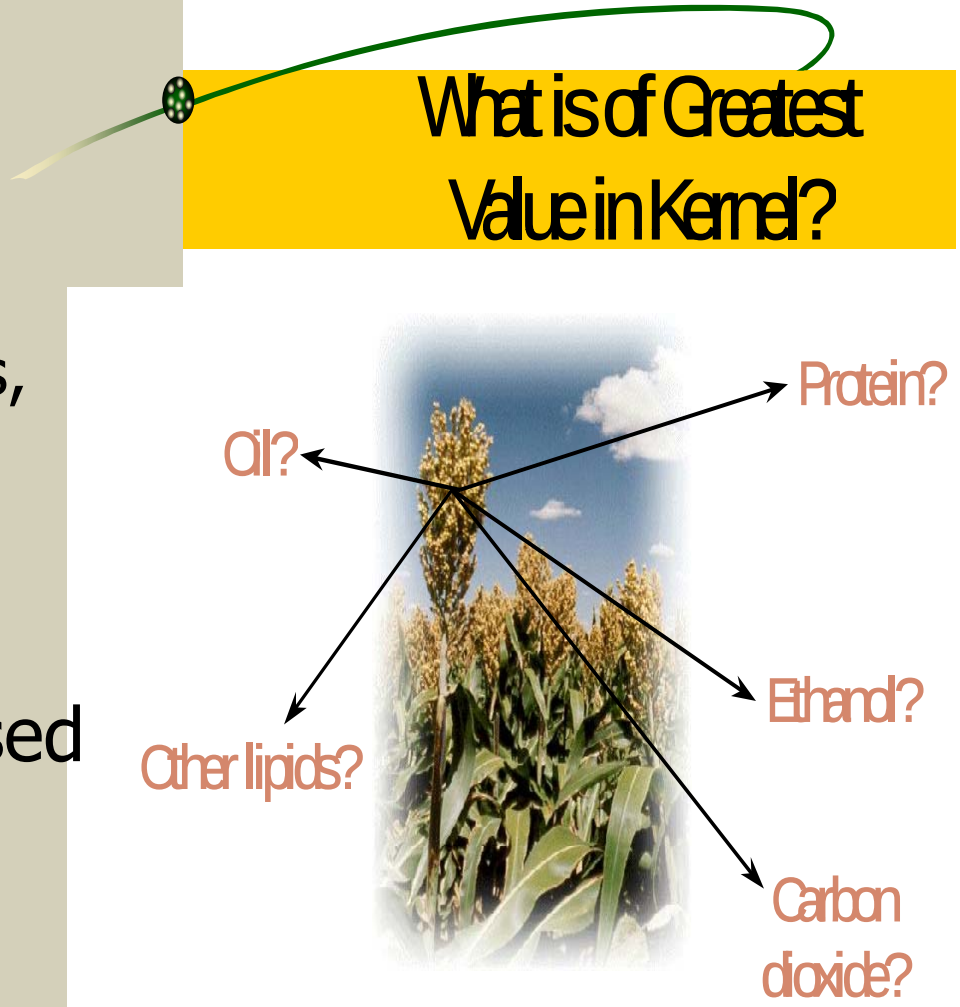
- Increase yield potential? – increased research and/or luck!
- Climate change to more adverse production conditions?
- Need to use limited irrigation?
- Control cost of production?
- Grain ethanol industry future?
- Potential as a non-GMO crop?
- Increased demand for feed grains in Mexico?

Improve Market Potential – Livestock Feed

- Large kernel size increases feeding value equal to corn
- Lack of mycotoxin problems during production

Improve Market Potential – Grain Ethanol

- Increase ethanol yield?
- Health products
  - Anti-oxidants (polyphenols, tannins)
  - Phytosterols
  - Policonsanols
- By-products have increased levels



Weed Management

- Pre options exist, but production in dry areas often reduces effectiveness (i.e. moisture to activate herbicides)
- Post control for broadleaves exist
- Biggest problem is post control of grasses

Future Increase in Ease of Weed Management – Post Control for Grasses

- ALS and ACCase resistant sorghum lines have been developed at KSU
- ALS resistant shattercane was crossed with grain sorghum lines (Tuinstra and Al-Khatib)
- ACCase resistance sudangrass genes were moved into grain sorghum (Tuinstra and Al-Khatib)
- ACCase and ALS resistant lines have been distributed by K-State to sorghum breeding programs
- This is a cooperative project with Dupont and all breeding programs have signed agreements with Dupont

ALS Herbicides (Post Grass Control)

- Nicosulfuron (Accent) or nicosulfuron + rimsulfuron (Matrix)
- Already have weeds that are resistant
- Therefore stewardship or management is going to be key to keeping the tool

ACCase Herbicides (Post Grass Control)

- Not all ACCase herbicides can be used
- ☐Two types of ACCase herbicides
- ☐Fops - yes
  - Fluazifop–Buytl (Fusilade)
  - Quizalofop–p –Ethyl (Assure II)
- ☐Dims - no
  - Sethoxydim (Poast)
  - Clethodim (Select)

As Value-Added Specialty Crop

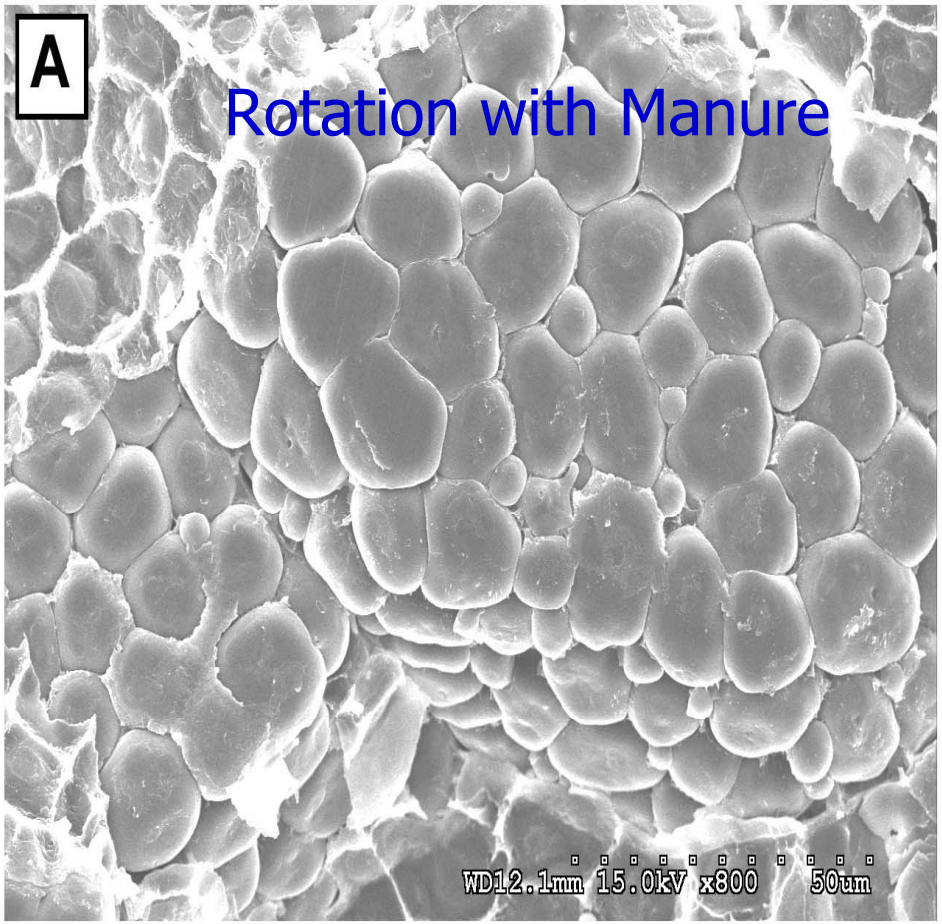
Food-Grade Sorghum

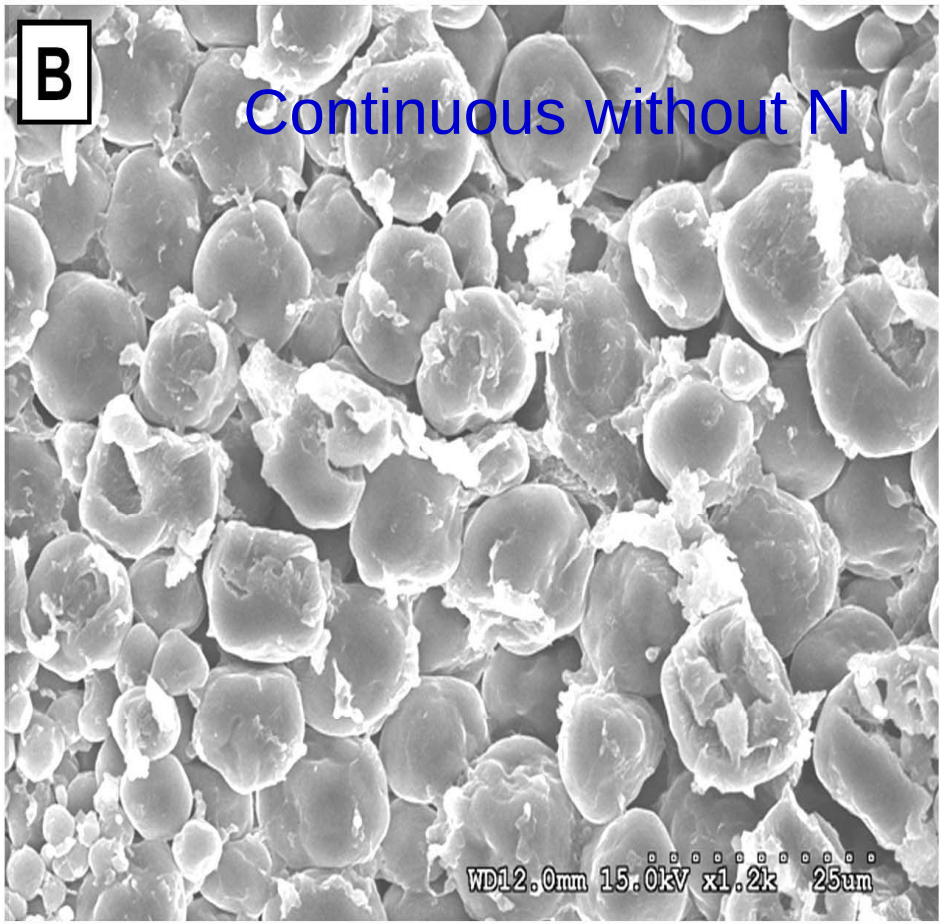
Availability of white grain tan-plant genotypes

Need to consider more than color!

- Hardness
- Starch properties
- Fermentation properties
- Taste

Production Practices Influence Hardness





TADD Equipment

TADD was the best measurement of hardness in this study as also found by Kaye et al. (2007)

Environment Influence on Hardness

TADD % Removed	2004	2005	
Mead Dryland Low N	73	22	
Clay Center Dryland	20	19	
Mead Dryland		17	
Hebron Dryland	27	14	
Orleans Dryland		14	
Mead Irrigated	21	18	
Clay Center Irrigated	21	17	
L.S.D. (0.05) = 1.42			

Hybrid differences

Food-Grade Hybrid	% Removed	Food-Grade Check	% Removed
NK 8828	25	Macia	19
Asgrow Eclipse	23		
Asgrow Orbit	21	Non-Food Checks	
KG 6902	25	DK 54-00	22
Fontanelle W-1000	26	DK42-20	20
NC+ 7W92	27	DK 53-11	21
NK 1486	28	NC+ 6C69	23
DK 44-41	24	P84Y00	20
Mycogen 14665	21	Mycogen 3696	29

LSD = 1.63%

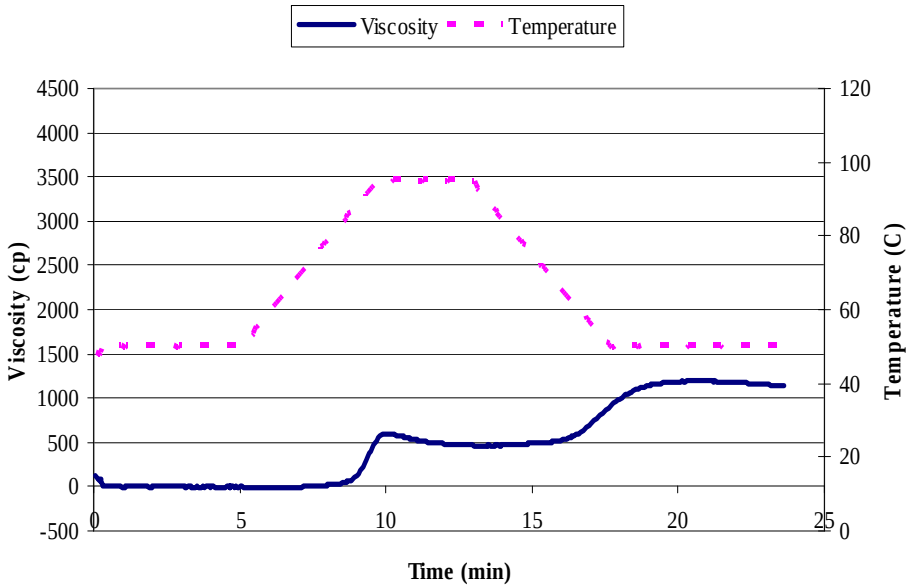
Rapid Viscosity Analysis

Sample Cup

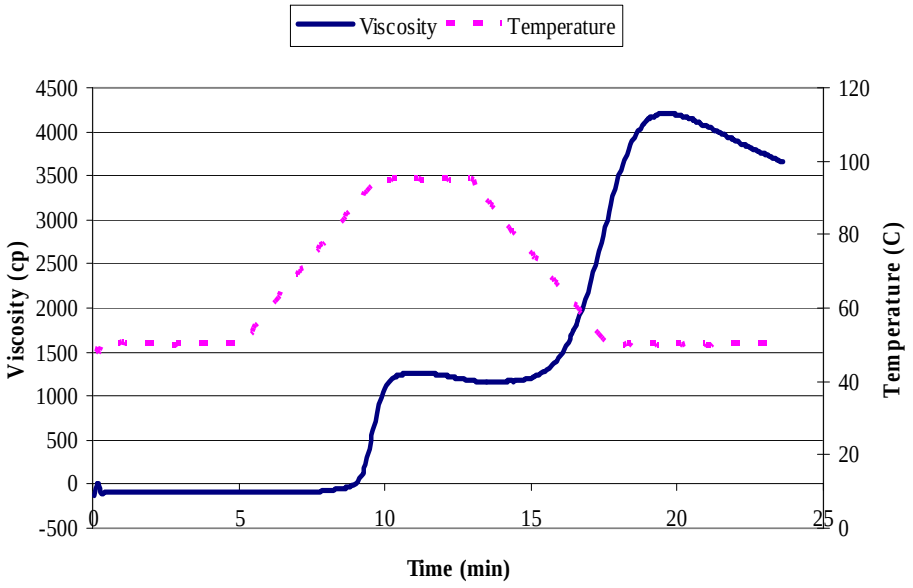
Paddle

Heating Unit

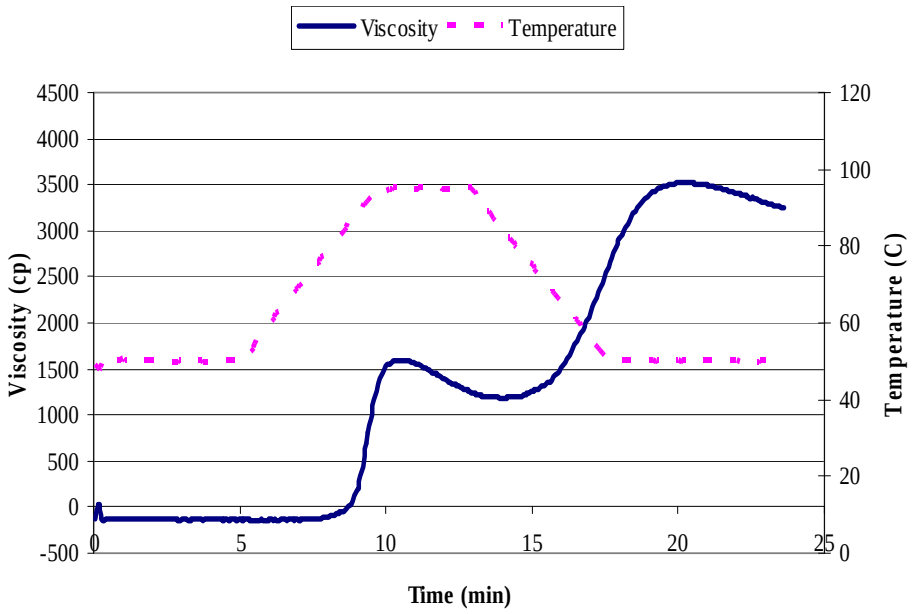
A. Mead Dryland with Low N 2004 (Low Yield, Soft Kernels, Low Starch)



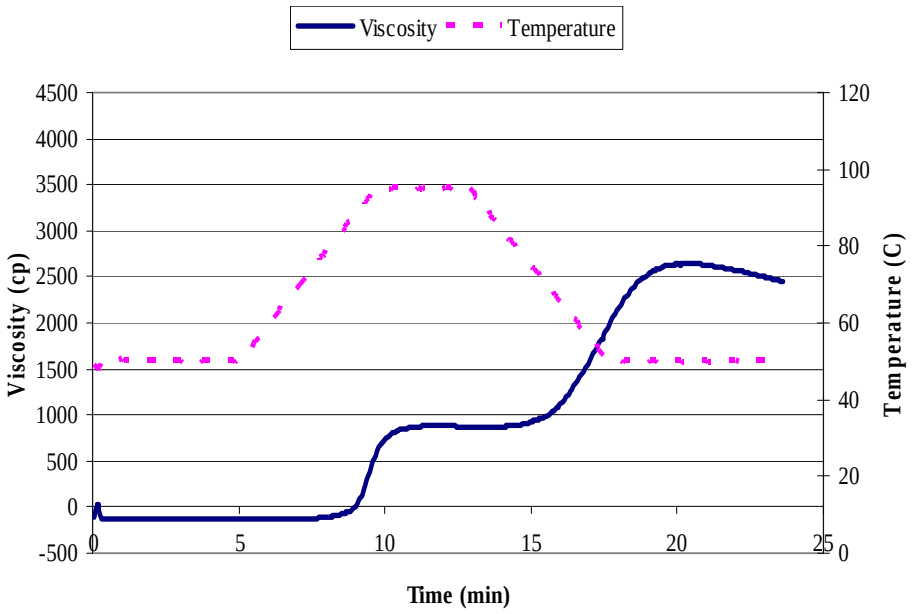
C. Clay Center Irrigated 2005 (High Yield)

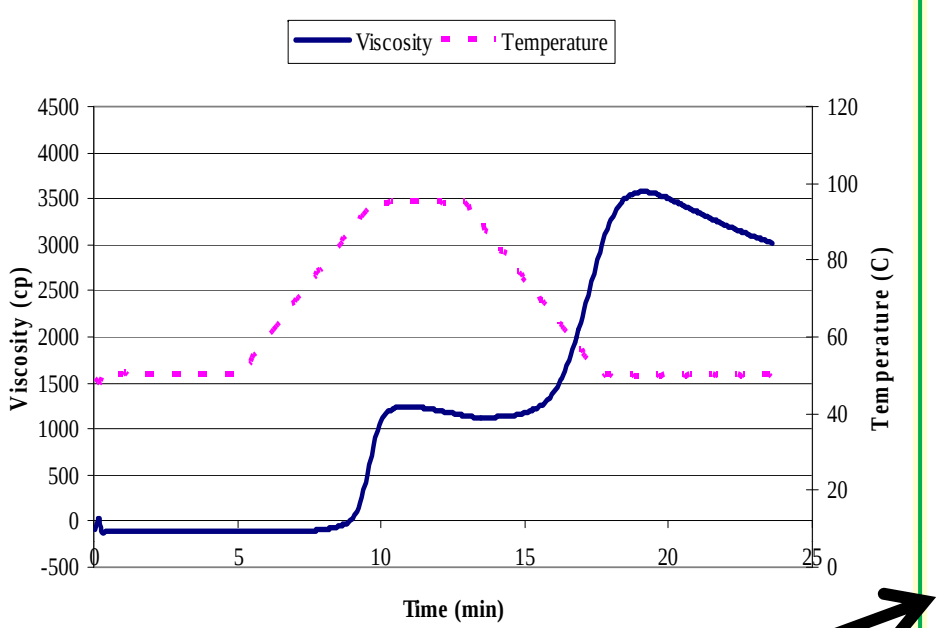


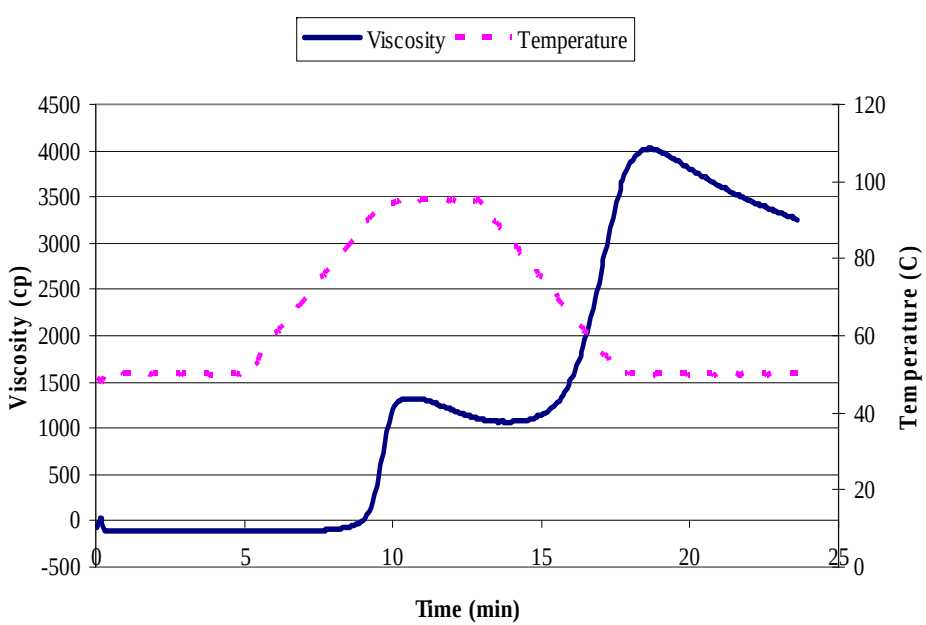
B. Mead Dryland with Low N 2005 (High Starch)



D. Orleans Dryland 2005 (Hard Kernels)

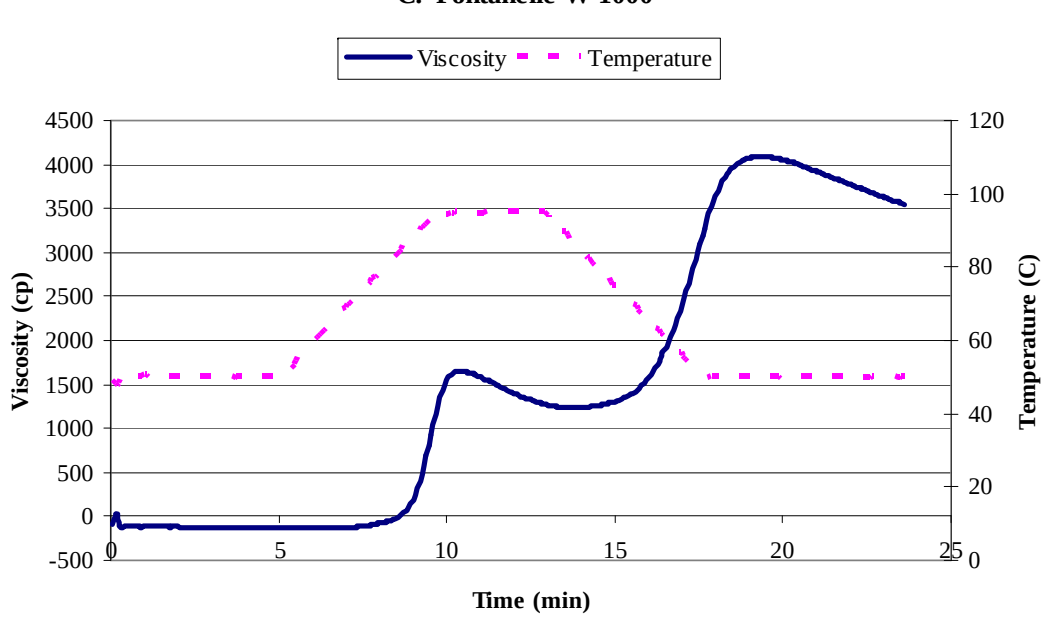






High Protein,
Low Starch

Low Protein,
High Starch

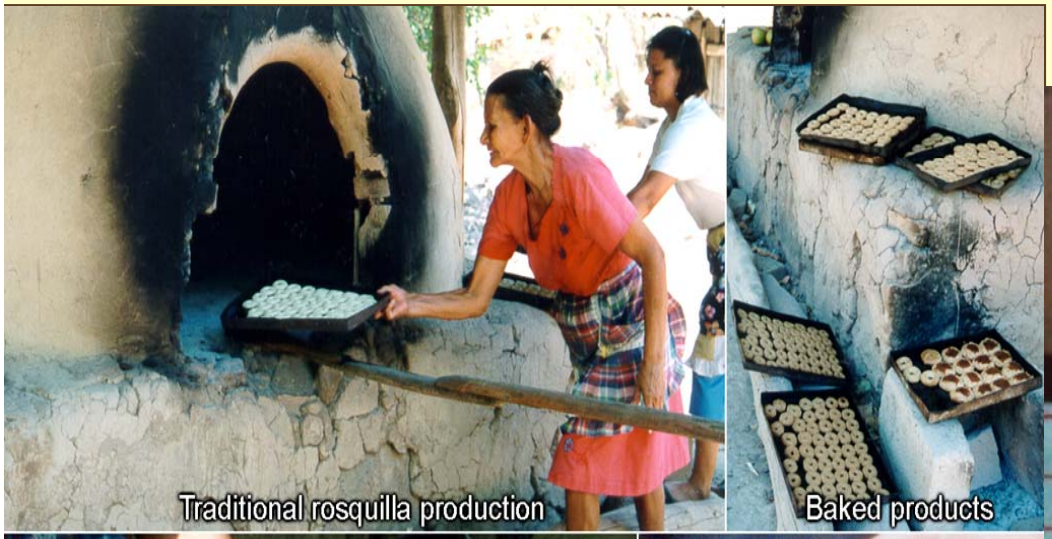


NE environments & sorghum hybrids available have capability to produce high quality food-grade sorghums with marketable traits for specific end-uses to benefit both producers and the food processor

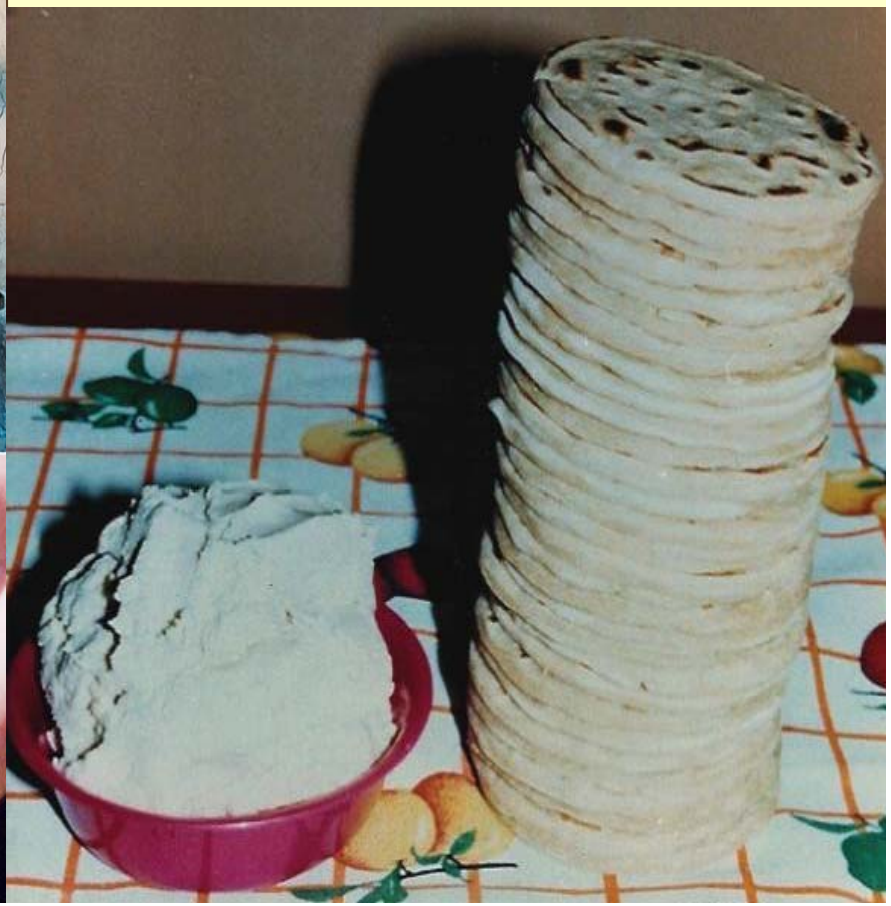
- Dryland with hybrids which produce hard kernels = dry milling for food use
- Irrigated with hybrids which produce soft kernels = wet mill, ethanol or beer production

Food Products

Central America Products (Maize flour substitution)


Traditional rosquilla production

Baked products




Tostacas


Quesadilla

Fermentation

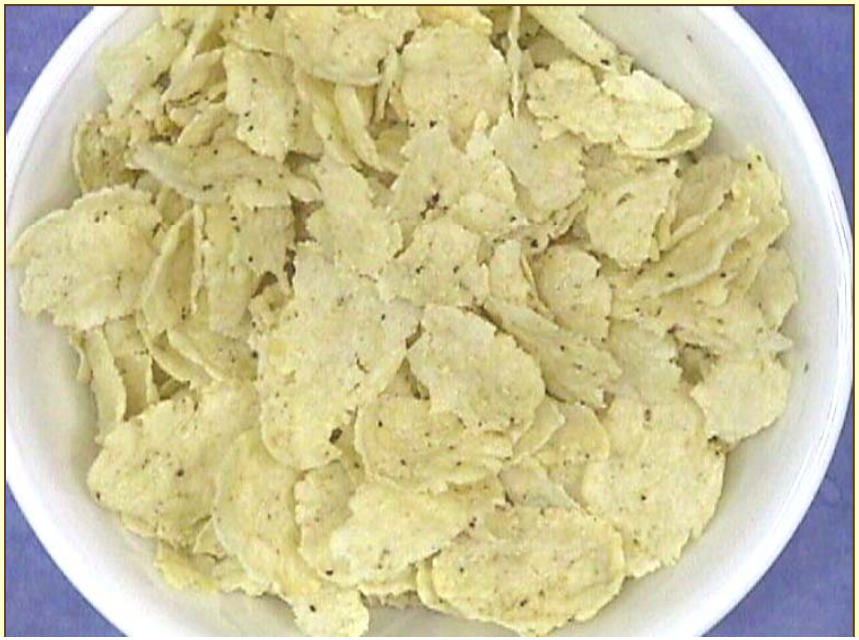
- Beer in Japan
- Beer production in Africa

Benefits of Sorghum Grain for Snack Foods

- Extrudes well
- Bland taste (accepts flavors readily)

Bland Taste and Ability to Accept Flavors

- Snack foods

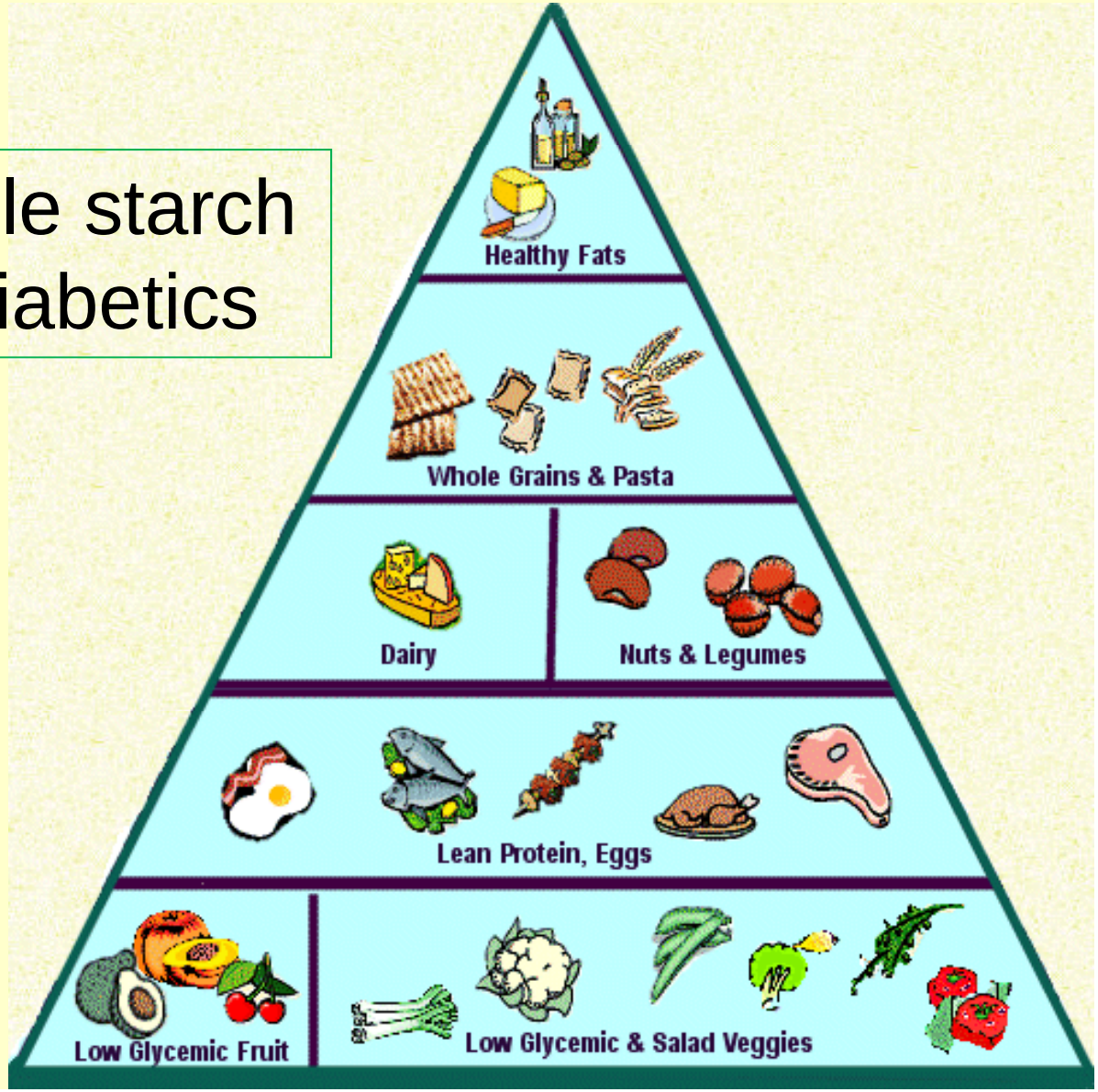


Celiac Sprue – Gluten Intolerance

High end foods for gluten intolerant population

Low Glycemic Index

- ❑ Slowly digestible starch
- ❑ Desirable for diabetics



Heart Healthy - Antioxidants

Bread products (wheat flour substitution)

Market as Non-GMO Crop

- Non-GMO crop
  - Advantage in some markets
  - An example: 2007
    - Sorghum traded as a premium to maize in EU due to an embargo on GMO products
    - Spain – 23.1 million bushels (10X increase)
    - Italy – 1.5 million bushels (none imported before)
  - Pet foods

Conclusion – Future Opportunities

- Grain sorghum has advantages
  - Abiotic stress tolerance
  - Suitability for multiple end-uses
- Challenges
  - Increasing yield potential
  - Further improving stress tolerance (water and N)
  - Pest management
  - Improving grain quality & value-added market development

Conclusion

- Increased research investment is essential
  - National public sector
  - International research centers
  - Private industry
- For grain sorghum to survive as a commodity crop and/or develop into an important value-added specialty crop