Increasing Resistant Starch in Wheat

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Dubcovsky Laboratory

Wheat in Our Diet

WHEAT

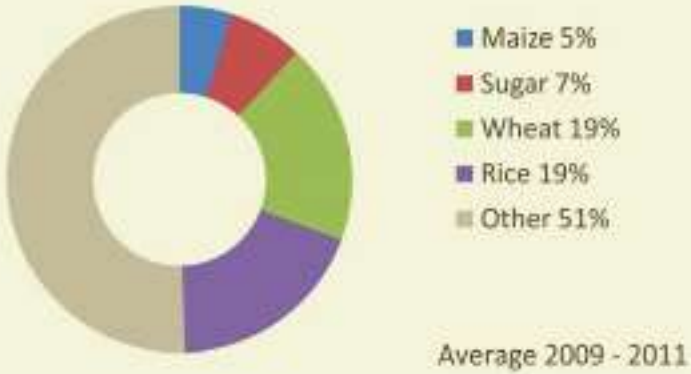
Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans.

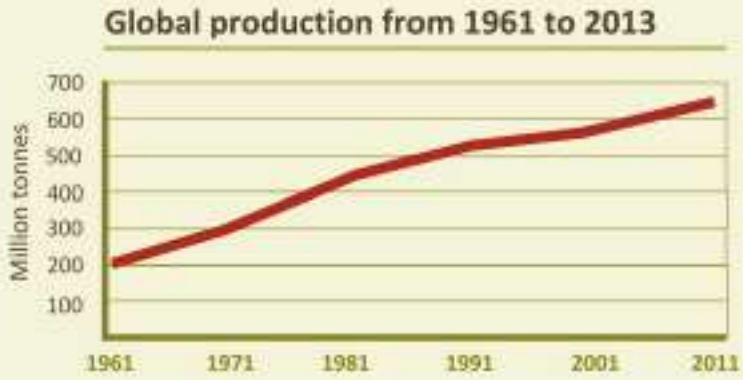
WHEAT IS THE LARGEST PRIMARY COMMODITY

GLOBAL PRODUCTION IS APROX.

700 million tonnes

WHEAT PROVIDES **19%** OF OUR TOTAL AVAILABLE CALORIES





(image courtesy of: http://www.fao.org)

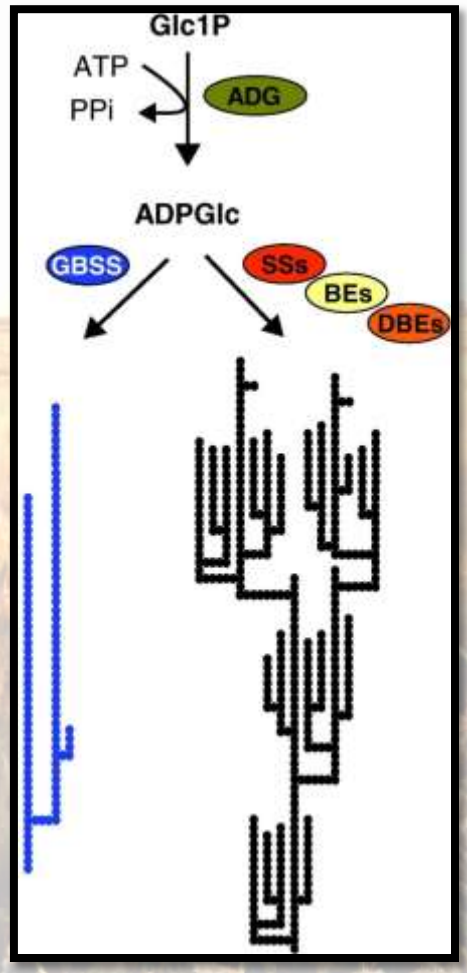
Wheat in Our Diet

- Starch is the major component of the wheat kernel (~50-70%).

- Improvements in starch composition have potential to deliver nutritional benefits.

Starch: Amylose and Amylopectin

- **Amylose**
  - **~ 20-30%**
- **Amylopectin**
  - **~ 70-80%**



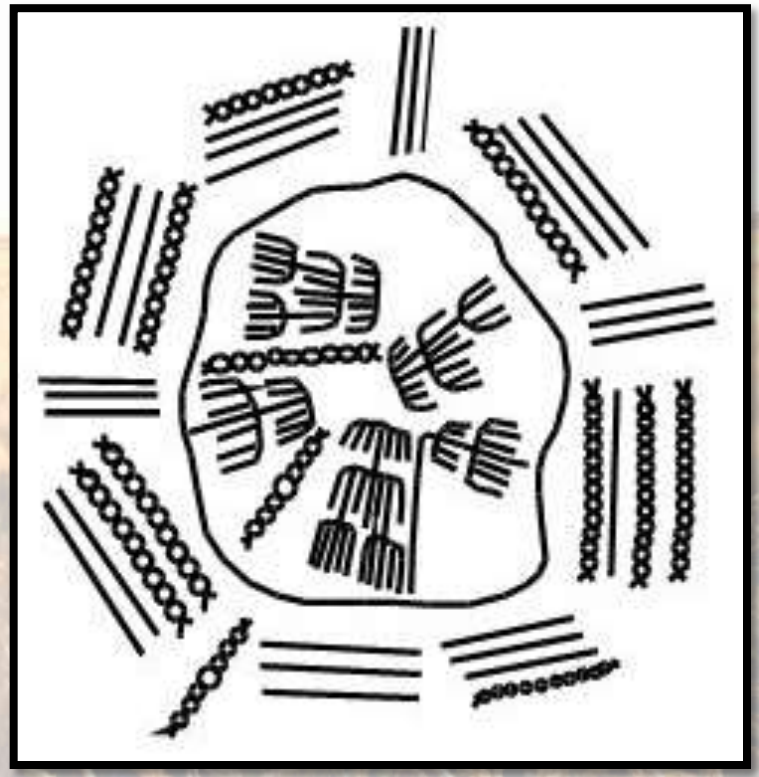
Amylose

Amylopectin

(image courtesy of: Santelia and Zeeman, 2011)

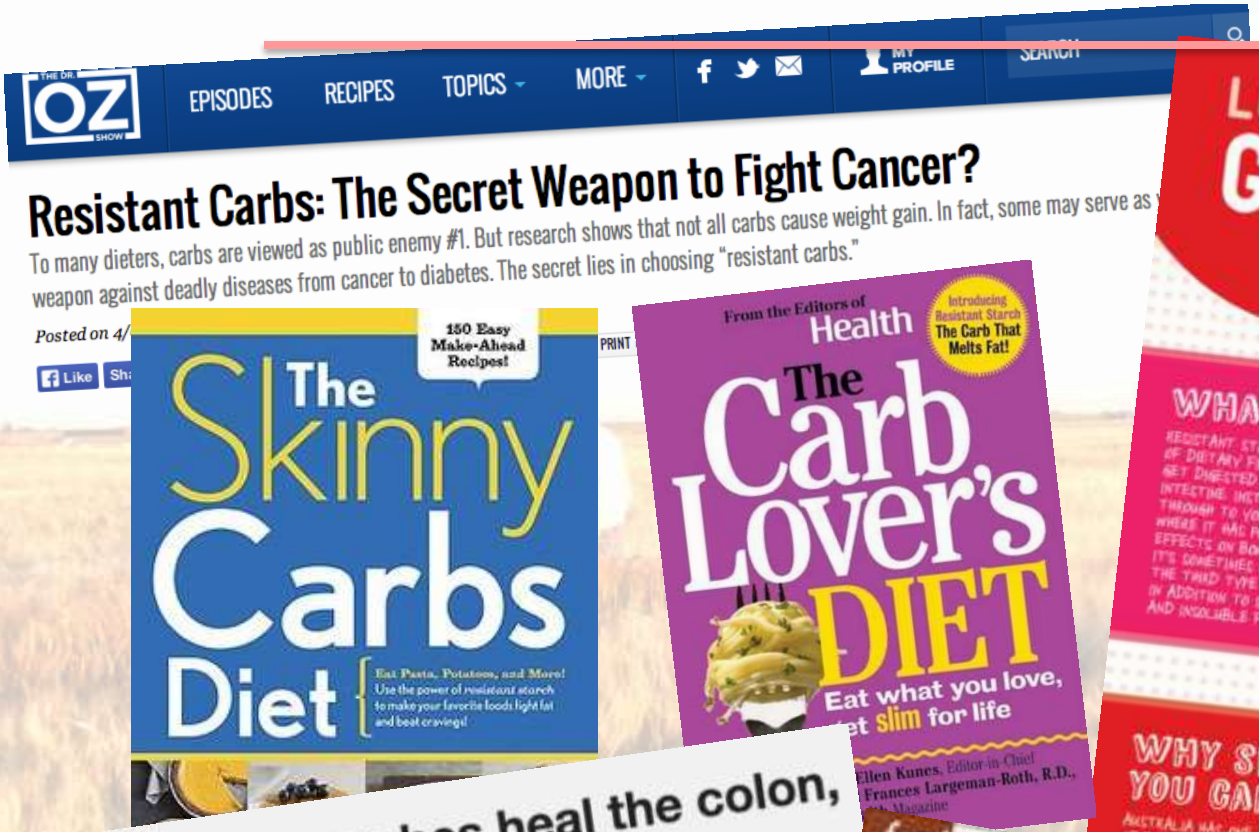
Resistant Starch (RS)

- High-amylose starch → **increased RS**
- Inaccessible to α-amylase digestion
- Component of dietary **fiber**



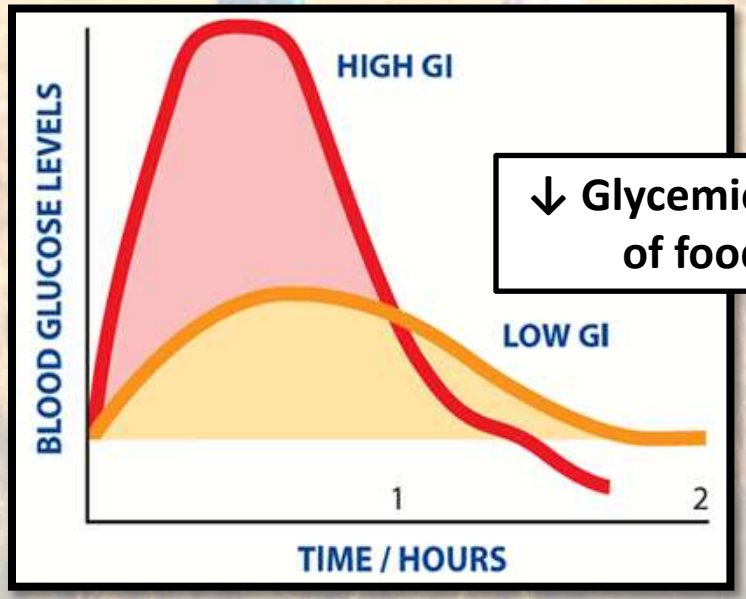
(image courtesy of: http://www.food-info.net/uk/carbs/starch.htm)

Health Benefits of Resistant Starch

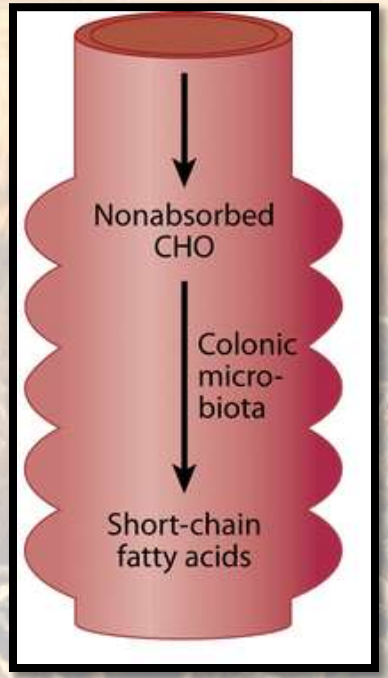


Health Benefits of Resistant Starch

- Reduced risk of diseases
  - Diabetes, obesity, heart disease and cancers of the colon and rectum
- Benefits in the large intestine and systemic health benefits



↓ Glycemic Index of foods



↑ Short Chain Fatty Acids

(image courtesy of: About Glycemic Index, The University of Sydney, 2011)

(image courtesy of: Binder, 2010)

Resistant Starch Content

Product	% Resistant Starch
Long grain rice (brown)	1.7
Rice pudding	0.2
Whole wheat breads	1.9 – 2.8
Refined grain products	0.2 – 1.1
Potato salad	1.0
Boiled potatoes	0.5
Legumes	3.4 – 3.5

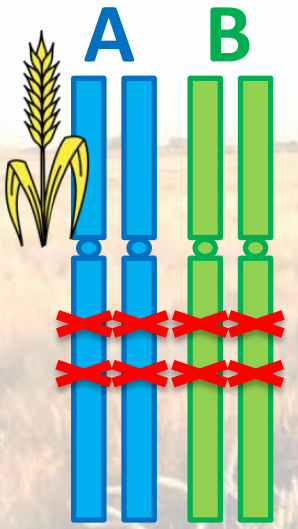
(Hendrich, 2010)

Consumption of Resistant Starch

- Recommended dietary fiber in the US
  - –19 to 38g per day
  - – <5% of Americans consume this
- Recommended resistant starch
  - – Australia's Division of Human Nutrition
    - 20g per day
  - – Americans consume ~5g per day
- **Breads and cooked cereals/pastas contribute ~40% of RS intake**

Starch Branching Enzyme II (SBEII)

- Catalyzes addition of branching points during amylopectin starch synthesis



- SBEIIa and SBEIIb

Previous Studies: Transgenic Approach

- Amylose content in the wheat grain can be increased by down regulating *SBEII* transcript levels.

- Down regulation of *SBEII* genes by RNAi → increase amylose content (25-70%)
  - Bread wheat (Regina et al., 2006)
  - Durum wheat (Sestili et al., 2010)


PNAS

High-amylose wheat generated by RNA interference improves indices of large-bowel health in rats

Ahmed Regina*†, Anthony Bird*‡, David Topping*‡, Sarah Bowden§, Judy Freeman§, Tina Barsby§, Behjat Kosar-Hashemi*†, Zhongyi Li*†, Sadequr Rahman*†, and Matthew Morell*†¶

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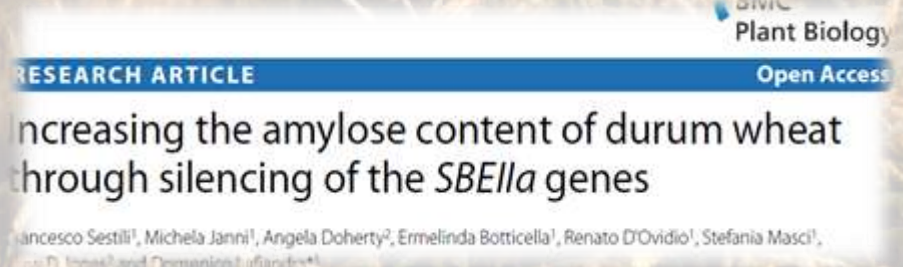

BMC Plant Biology

RESEARCH ARTICLE Open Access

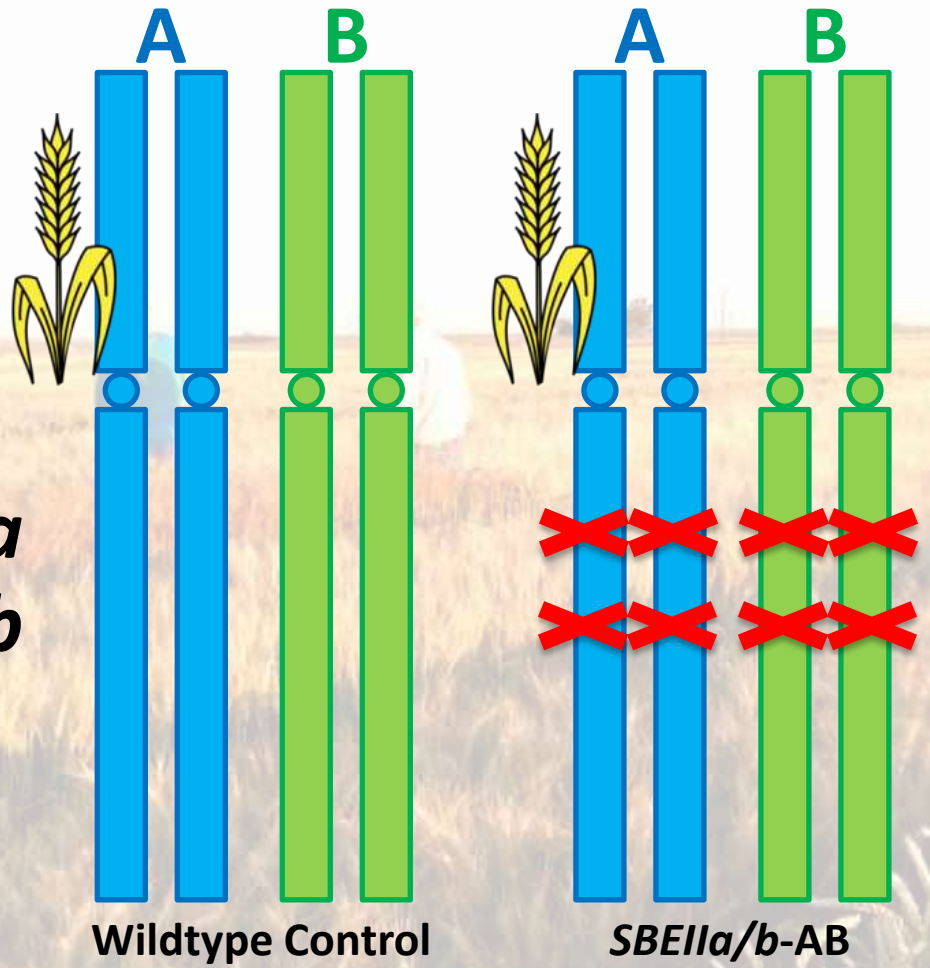
ncreasing the amylose content of durum wheat through silencing of the *SBEIIa* genes

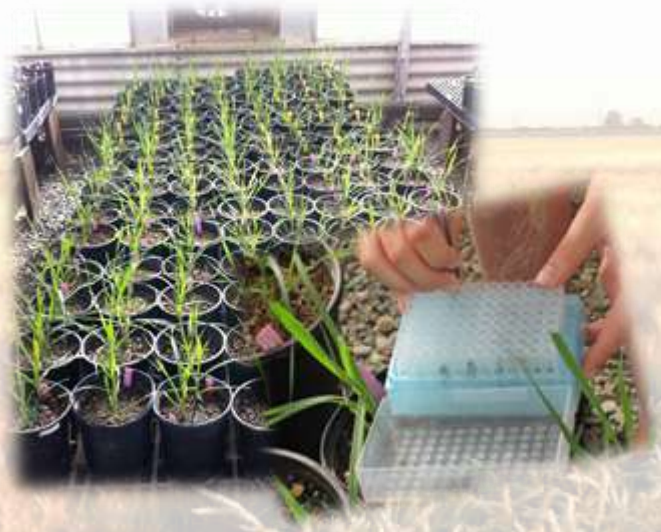
ancesco Sestili[1], Michela Janni[1], Angela Doherty[2], Ermelinda Botticella[1], Renato D'Ovidio[1], Stefania Masci[1],

Alternative approach: TILLING *SBEII* genes

- Commercialization of transgenic wheat has not yet been implemented
- **TILLING**
  - **Targeted Induced Local Lesions in Genomes**
  - Induce mutations using a chemical mutagen
  - Screen for mutations in *SBEII* genes

Combine *SBEIIa* + *SBEIIb* Mutations

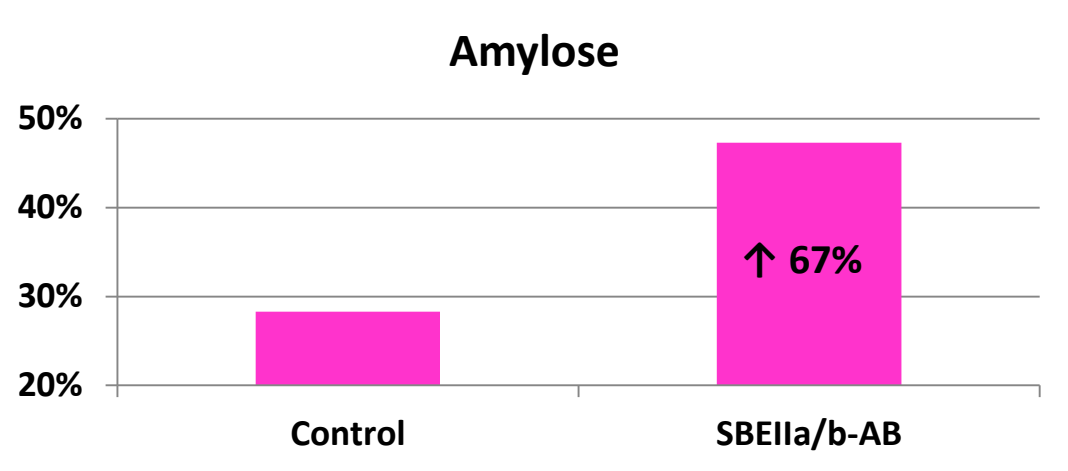


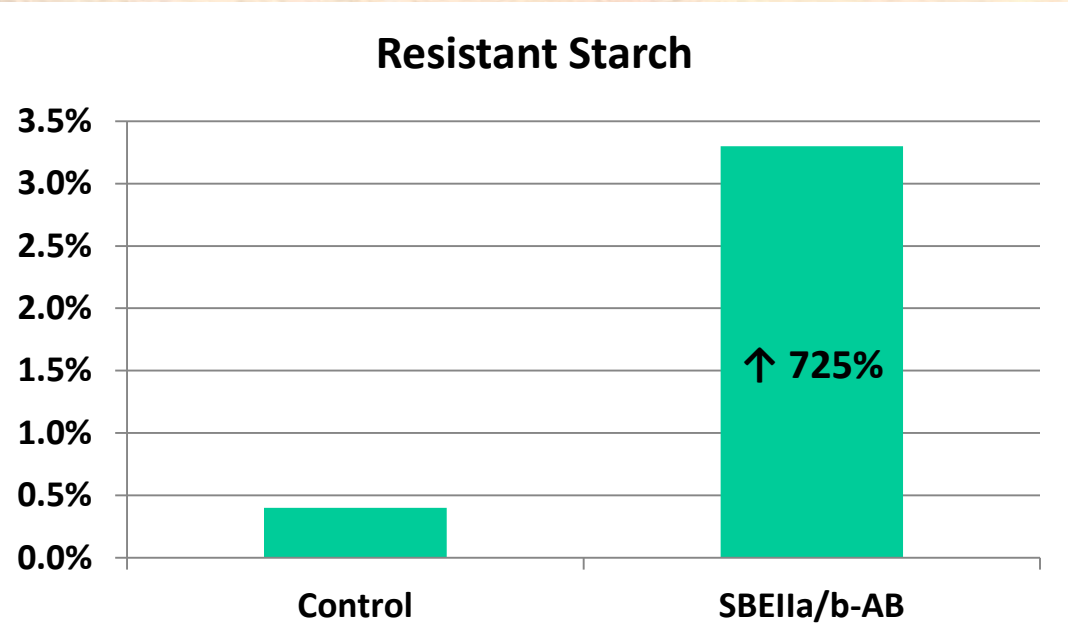


A Genome B Genome

(Hazard et al., 2014)

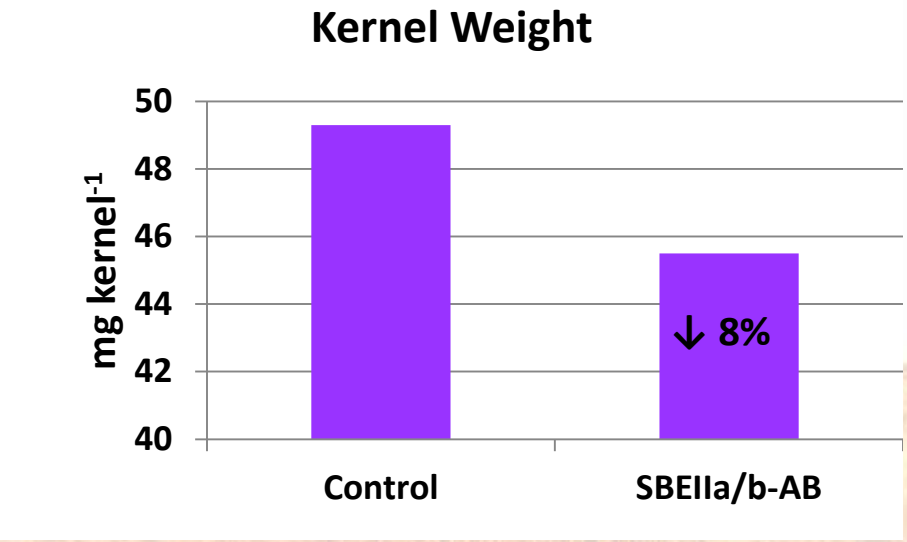
Results

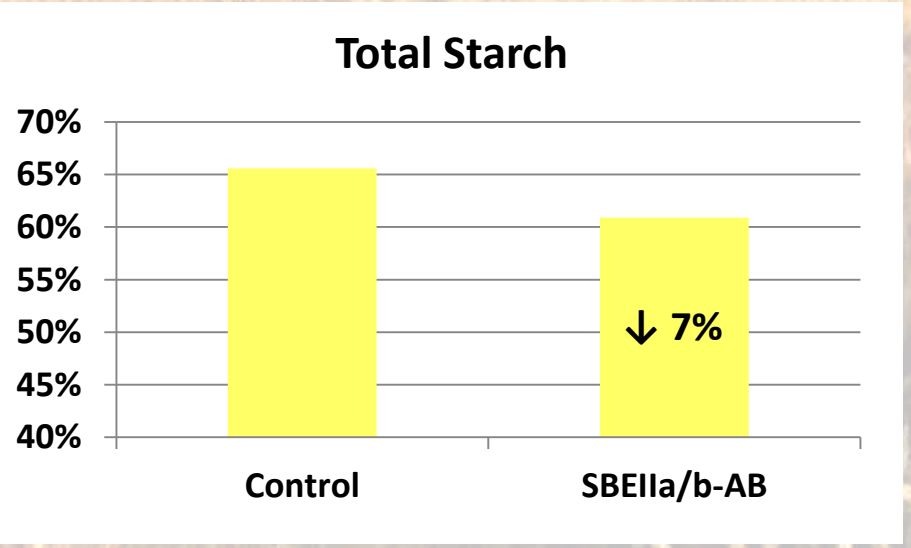




(Hazard et al., 2014)

Results

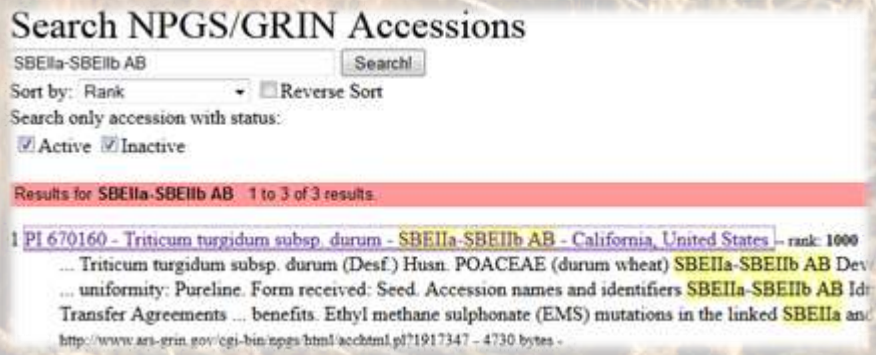




(Hazard et al., 2014)

Hazard et al. 2014

- **SBEIIa/b-AB line registered**
  - PI # 670160
- **Germplasm Resource**
  - National Center for Genetic Resources Preservation (NCGRP)
  - Germplasm Resources Information Network (GRIN)



Goals for Current Experiments

Evaluation of *SBEIIa/b*-AB Mutant Line

- Agronomic characteristics
  - Yield trials in 3 California locations
- Quality characteristics
  - Collaboration with California Wheat Commission Milling and Baking Lab
  - Grain, semolina and pasta quality

Agronomic Characteristics

- 3 Locations
  - Sacramento Valley in Davis, CA
  - San Joaquin Valley in Five Points, CA
  - Imperial Valley in Holtville, CA
- Yield Traits
  - Total Yield
  - Spike density
  - Spikelet number
  - Kernel number
  - Kernel weight

Preliminary Results

Agronomic Characteristics

- Yield penalties are observed in *SBEIIa/b*-AB lines
- ~5% decrease in kernel weight
- ~5-10% decrease in overall yield

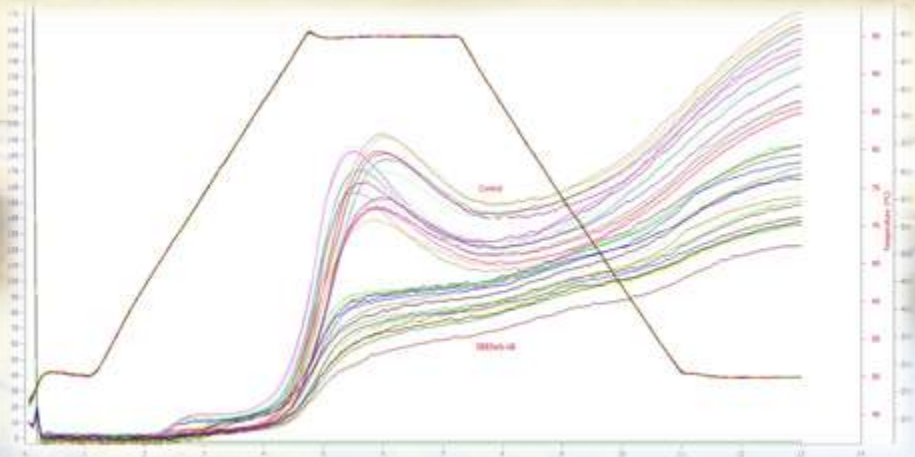
Grain and Semolina Quality Characteristics

- **Grain Quality**
  - Test Weight
  - Kernel Size Distribution
  - Protein
  - Ash
  - Hard and Vitreous of Amber Color (HVAC)
- **Semolina Quality**
  - Milling Tests
  - Speck
  - Color
  - Alveograph
  - Protein
  - Ash
  - RVA
  - Falling Number
  - Wet Gluten

Preliminary Results

Grain and Semolina Quality

- Decrease in test weight (~3%)
- Decrease in semolina extract (~4%)
- Increase in falling number (~40%)
- Changes in alveograph parameters
- Changes in RVA parameters



Pasta Quality Characteristics

- **Pasta Quality**
  - Color
  - Cooked Weight
  - Cooking Loss
  - Firmness

Preliminary Results

Pasta Quality

- Increase in cooking loss (~20%)
- Increase in firmness (~12%)

Future Directions

- Test RS in pasta
- Gut fermentation study in rodents
  - Cecal size, cecal pH, short chain fatty acids, gut peptides...
- Transfer and test mutations in common wheat

(rat image courtesy of: http://www.criver.com)

Acknowledgments

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