

Genetic and QTL Analysis of Maize Kernel Composition Traits

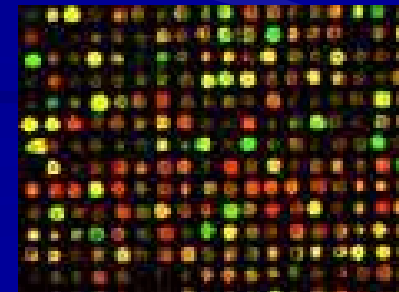
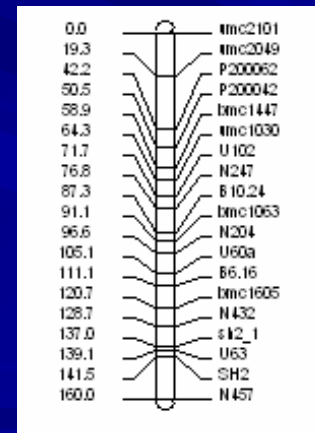
Sofia Silva

Richard Johnson

Martin Bohn

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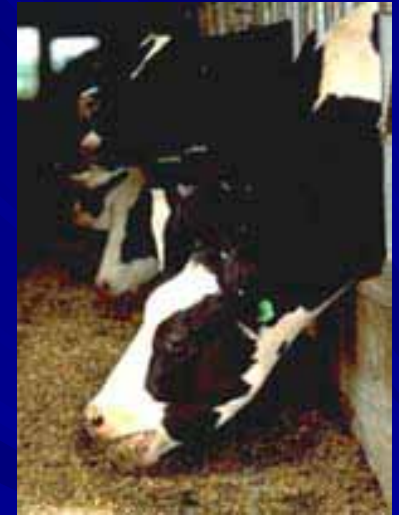
Importance

■ Maize grain is a Great Source of Energy with Many Uses

- Human Food
- Animal Feed
- Industrial Use

- Starch
- Sweeteners
- **ETHANOL**

➤ Starch Protein Oil

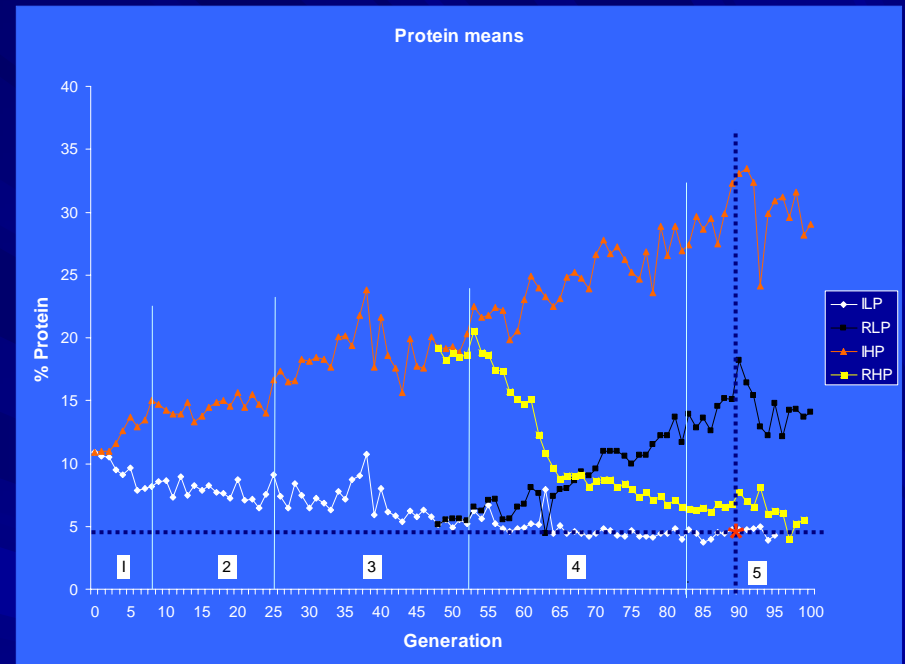


Rationale

■ **Ninety Generations of Selection for Low Protein Resulted in Strains**

– **Approximately 75% Starch & Only 4% Protein**

■ **Evaluate for ILP QTL Alleles that improve Starch concentration in a historically elite background**



Objectives

- **Map QTL for Starch, Protein, Oil, and kernel Weight in a (ILPXB73)B73 S₁, S₃ Populations and in the Two Populations Combined**
- **Perform Principal Components analysis (PCA) on the traits and Map QTL using the Principal Components as Traits**
- **Compare QTL Across Two Different Generations**
- **Compare QTL with Other Studies**

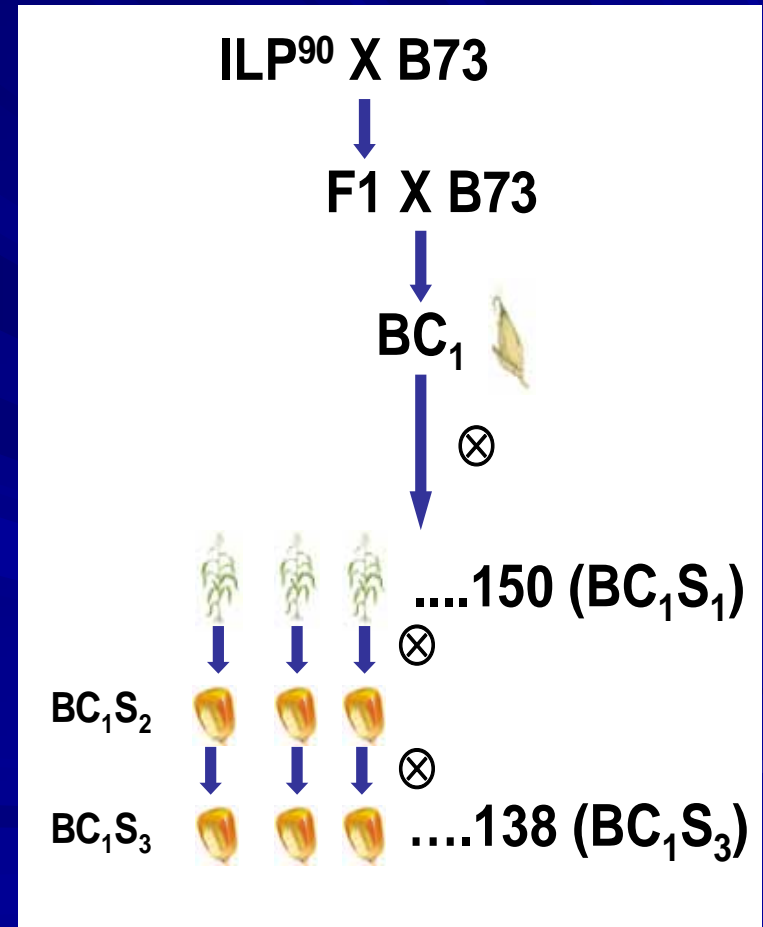
Material and Methods

Genetic materials

- **150 (ILP X B73) B73 S₁ families**
 - 2 Reps in 1993, 1994, 2003, 2004, and 2005
- **138 (ILP X B73) B73 S₃ families**
 - 2 Reps in 2002 and 2005

Experimental design

- South Farms of Urbana
- Randomized Alpha (0,1)
- 15 ft plots, 15 plants/row



Material and Methods

■ Phenotypic Data Collection

- NIR ~ Starch, Protein & Oil
- 100K weight

■ Genotypic Data Collection

- BC₁S₁
 - Map 142 markers
(1282.5 cM)
- BC₁S₃
 - 114 markers



Means

BC₁S₁

Parameters	Starch	Protein
	g kg ⁻¹	g kg ⁻¹
Means		
ILP	757.2	55.1
B73	677.4	115.9
BC ₁ S ₁	701.1	95.7
Range (BC ₁ S ₁)	660.9 – 718.5	83.5 – 126.6

BC₁S₃

Parameters	Starch	Protein
	g kg ⁻¹	g kg ⁻¹
Means		
ILP	745.0	63.8
B73	674.3	125.3
BC ₁ S ₃	689.6	111.6
Range (BC ₁ S ₃)	656.8 – 709.9	91.1 – 147.1

Transgressive Segregation

- Families with **Lower Starch** than both parents
- Families with **Higher Protein** than both parents

QTL detected for Individual Traits in BC₁S₁ Population

❖ Additive Effects were significant

Trait	N*	R ² (%)	p (%)	Alleles
Protein	10	39.4	46.8	Most B73
Oil	9	38.2	44.4	Both
Starch	8	35.2	54.7	Most ILP
KWeight	10	38.8	63.1	Most ILP

2 QTL in common between Starch, Protein and Oil

5 QTL in common between Starch and Protein

4 QTL in common between Starch and Oil

Principal Component Analysis (PCA) BC₁S₁

PCA Loadings

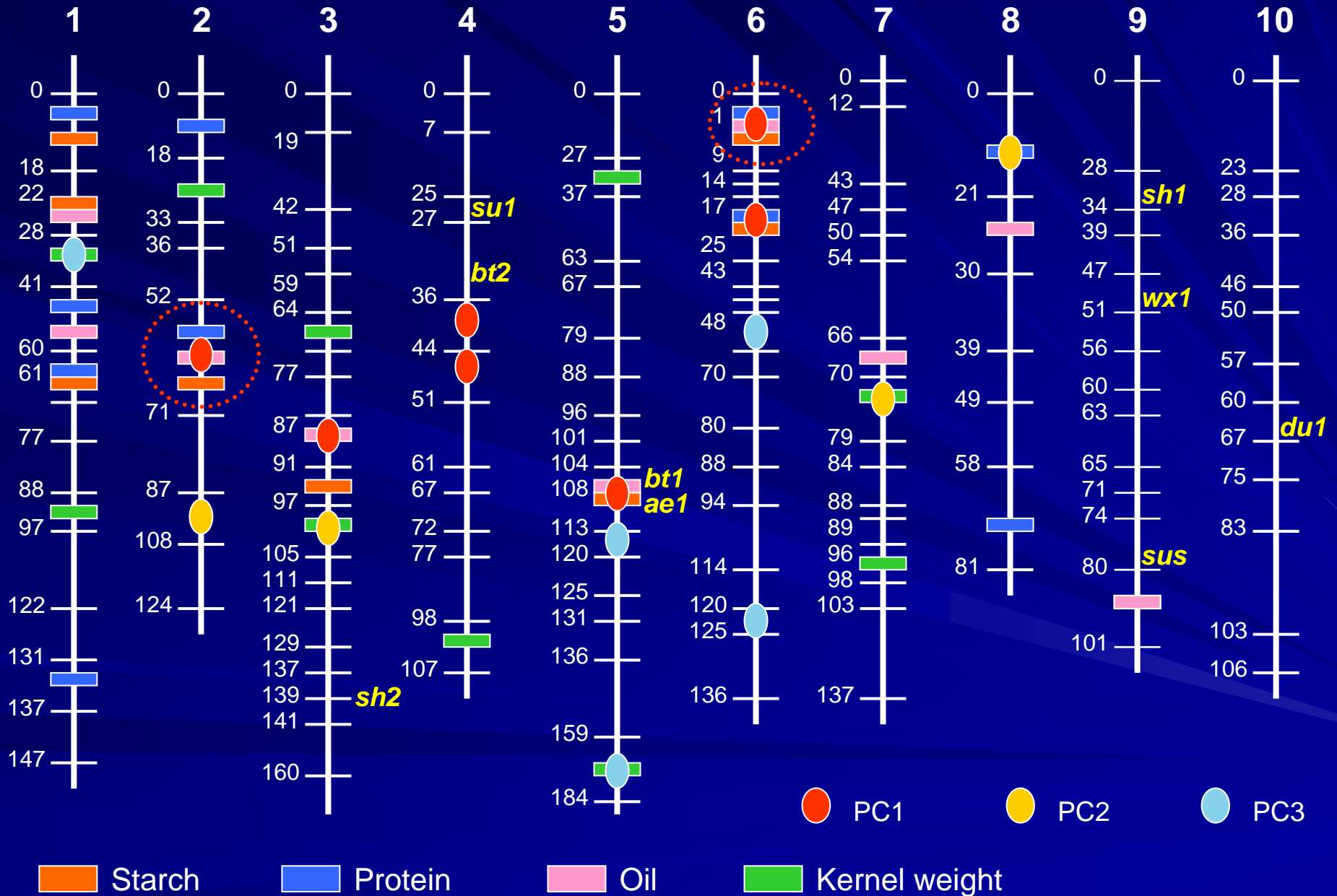
Parameter	PC1	PC2	PC3
Eigenvalue (λ)	2.19	0.93	0.74
% of total variation	54.7	23.1	18.6
kernel traits loadings			
Starch	- 0.63	- 0.20	0.18
Protein	0.58	0.43	- 0.20
Oil	0.41	- 0.28	0.87
Kernel weight	- 0.31	0.84	0.43

Detected QTL

PC	N	R ² (%)
PC1	7	27.7
PC2	4	24.9
PC3	5	34.3

■ **10 QTL** identified for **PCs**
common to QTL found for
Individual Traits

QTL detected for Traits & PCs in BC₁S₁ Population



BC₁S₃



QTL detected for Individual Traits in BC₁S₃ Population

Trait	N	partR ² (%)	Alleles
Protein	5	7.7 – 9.4	Most B73
Oil	2	7.2 ; 8.3	ILP
Starch	3	7.3 – 12.5	ILP
KWeight	7	7.7 – 23.2	Both

ILP contributed All the Alleles for Increasing Starch Concentration and Both Alleles for Increasing Oil

Most of the Additive and Dominance Effects on Increasing Protein came from B73 Alleles

No Epistatic Interactions were detected for any of the Traits

Principal Component Analysis (PCA) BC₁S₃

PCA
Loadings

Parameter	PC1	PC2	PC3
Eigenvalue (λ)	1.97	0.99	0.94
% of total variation	48.65	25.21	24.17
kernel traits loadings			
Starch	0.67	0.12	- 0.24
Protein	- 0.68	0.11	0.19
Oil	0.23	- 0.68	0.69
Kernel weight	0.20	0.72	0.66

PC-QTL

PC	N	PartR ² (%)
PC1	8	6.8 – 10.3
PC2	7	6.8 – 26.3
PC3	6	7.2 – 13.4

**11 QTL identified for the
PCs were common to QTL
identified for Individual
Traits**

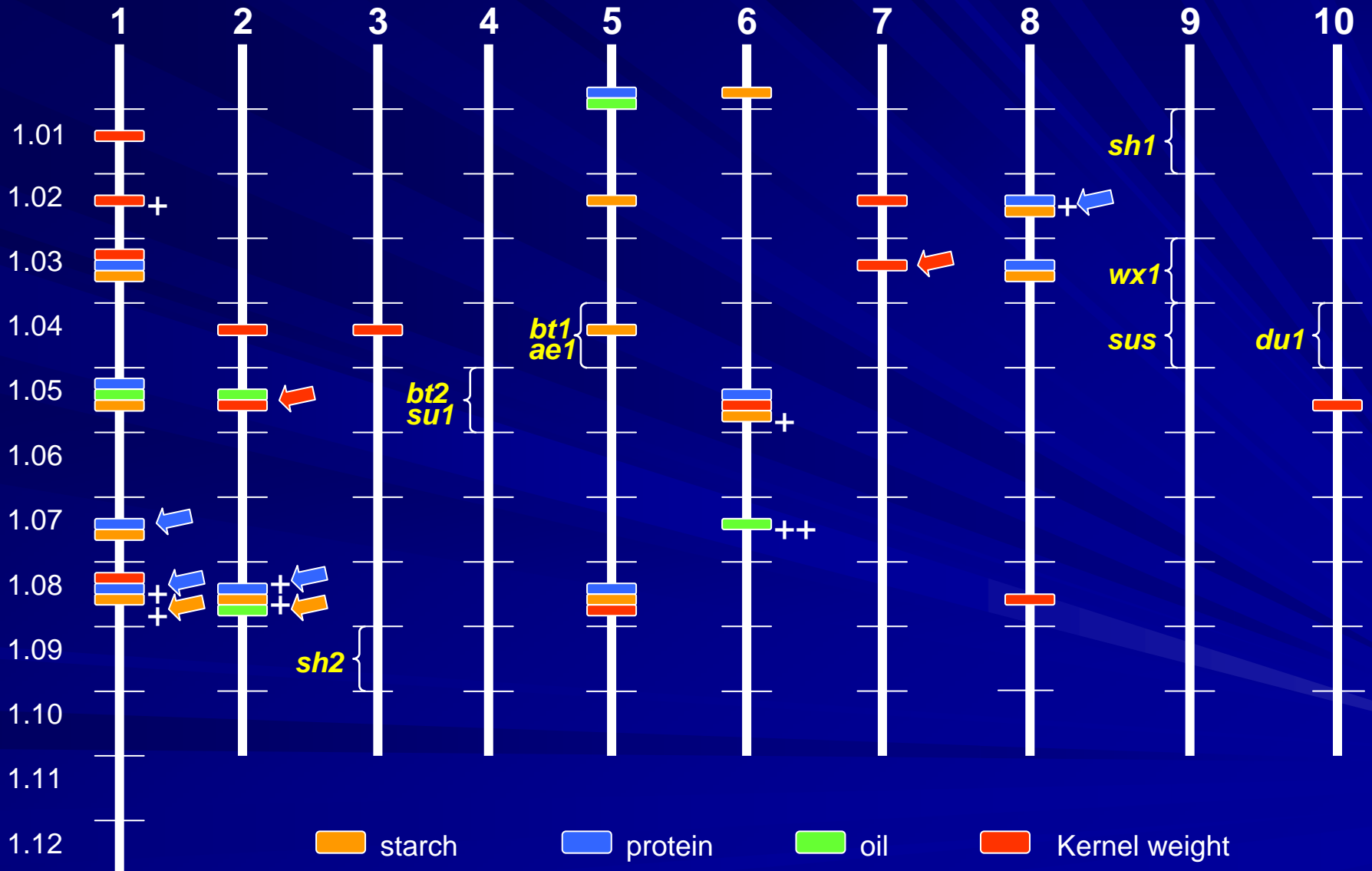
QTL detected for individual traits for the BC₁S₁ and BC₁S₃ combined analysis

Trait	N	partR ² (%)	Alleles
Protein	13	3.2 – 7.7	Most B73
Oil	7	3.7 – 4.5	ILP
Starch	15	2.1 – 7.2	Most ILP
KWeight	14	2.4 – 10.8	Both

ILP contributed Additive Effects for Increasing **Starch**
Most Additive Effects on Increasing **Protein** came
from **B73** Alleles

All Additive and Dominance Effects for Increasing **Oil**
came from **B73** Alleles

QTL detected for individual traits in the combined analysis



Summary & Conclusions

BC₁S₁ BC₁S₃ and Combined Analysis

- **ILP Improved B73 for Starch Composition**
- Some QTL were Significant for More than one Trait



Pleiotropic or linked QTL?

- Only One QTL identified for Starch mapped near the location of a Gene known to affect Starch Biosynthesis
(*bt 1*)
 - **Other Genes not in the Pathway Influencing % Starch (Transcription Factors ?)**

Summary & Conclusions

Comparison of QTL in the Three analysis

- 2 QTL for starch
- 4 QTL for protein
- 2 QTL for kernel weight



MAS

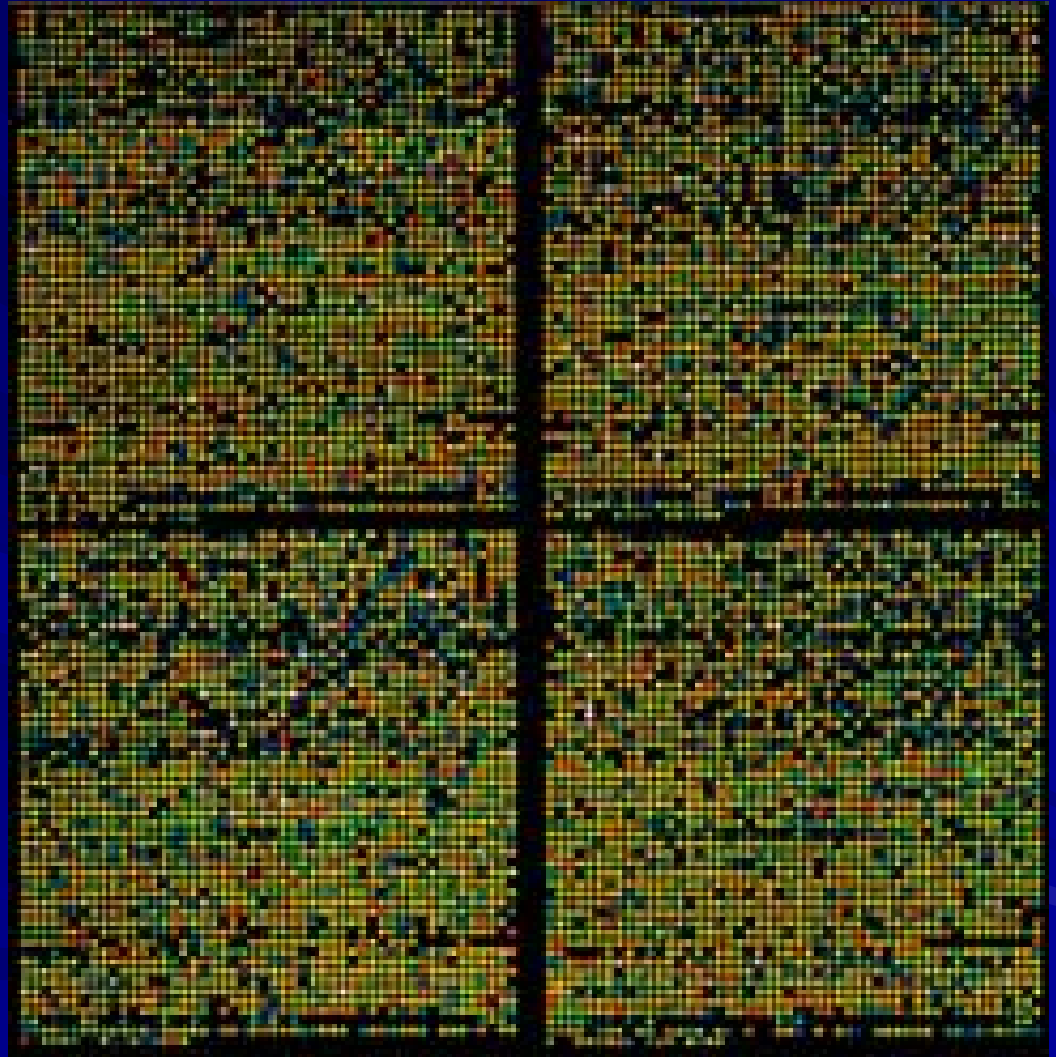
Comparison of QTL in this Study with Other Studies

- 11 QTL detected for starch across different genetic backgrounds



**New Gene
Discovery**

Microarray Experiment



Microarray Data Analysis

- Top families **High & Low Starch** selected

 - **BC1S1 & Testcross**

- Ear and Leaf tissue collected

10, 15 and 20 DAP

Conditions

BC₁S₁

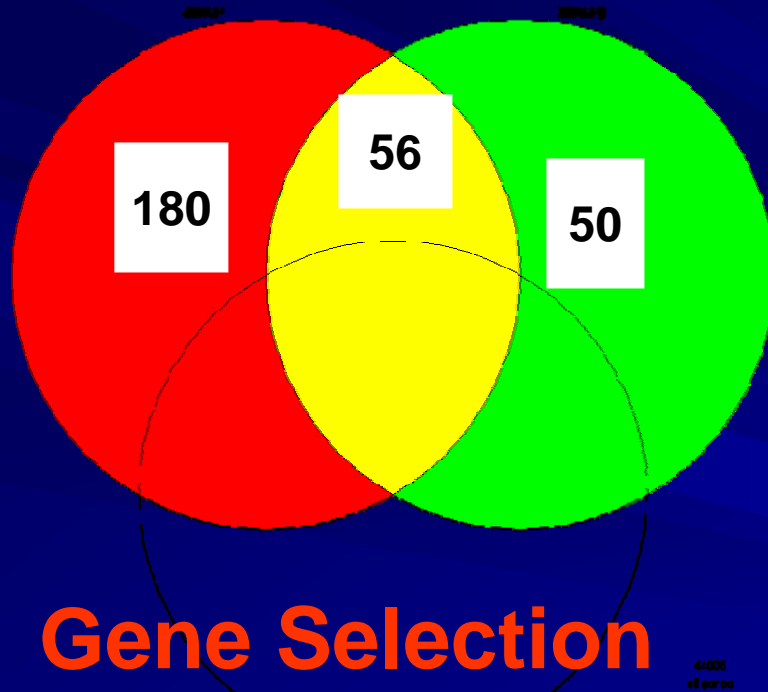
2004_11(12,13)DAP → **Kernel**
2004_20DAP
2005_15DAP → **Kernel & Leaf**
2005_20DAP → **Kernel & Leaf**

Testcross

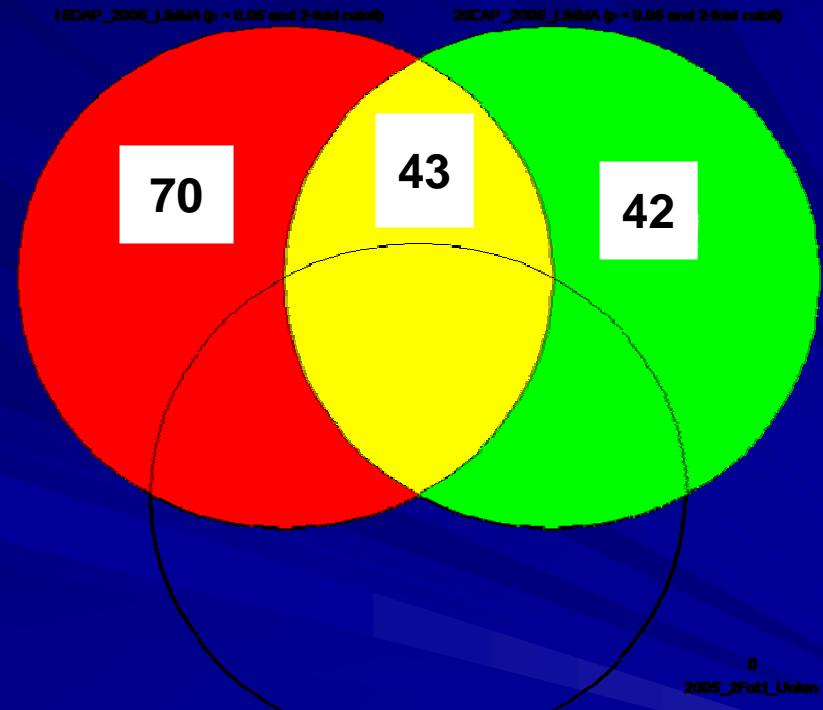
2004_11(12,13)DAP → **Kernel**
2004_20DAP → **Kernel**
2005_10DAP → **Kernel & Leaf**
2005_15DAP → **Kernel & Leaf**
2005_20DAP → **Kernel & Leaf**

Some Results

2004 vs 2005 (UP, Union in DAPs, Intersection in years)



15DAP vs 20DAP with 2005 Data

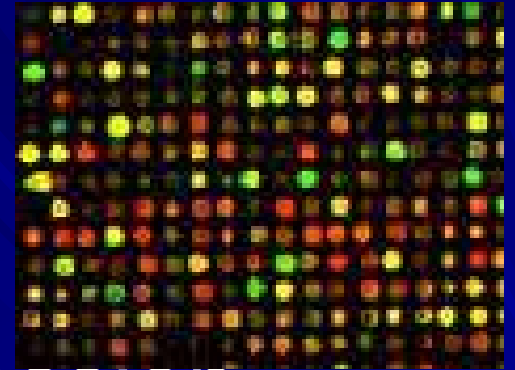


Gene Selection

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \lambda_k + \delta_l + \lambda \delta_{kl} + \varepsilon_{ijkl}$$

• 135 Genes selected

Next



- Quantify ESTs - qPCR
- Map ESTs Associated Expression Differences
- Relate EST Map Position to QTL for Starch concentration
- Next Generation Testcross Progenies with Grain Yields Reasonably Similar to Commercial Checks, MAS

Acknowledgements

Dr. Troyer – Troyer - Darwin Fellowship

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Don Roberts

All the members of the lab

Undergrad and High School
Students



Questions?

Genetic Materials

(ILP×B73)B73 S₃ × FR616



138 Testcross Lines

✳ Evaluated in 1999,
2001 and 2002

- 12 Reps

- 10 hybrid checks

yield

starch

Testcross

Bu/acre

g Kg⁻¹

Mean

142.72

653.2

Range

114.5 - 156.5

645.4 – 655

Checks

Range

105.8 - 178.7

588.0 - 646.6

