

# Heritability and QTL for Popping Characteristics in Sorghum Grain

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# Pop sorghum?

- Several companies already sell popped sorghum
- Increasingly popular with niche consumers



- Not the subject of the amount of selective breeding that popcorn has received
- Few releases of improved lines for popping (ex. SA389)

# Objectives for this study....

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- Determine the heritability of popping quality traits in *Sorghum*
- Determine the relative effects of genotype, environment, and genotype x environment for popping quality
- Identify QTL markers for popping quality

# Population and Experimental Design

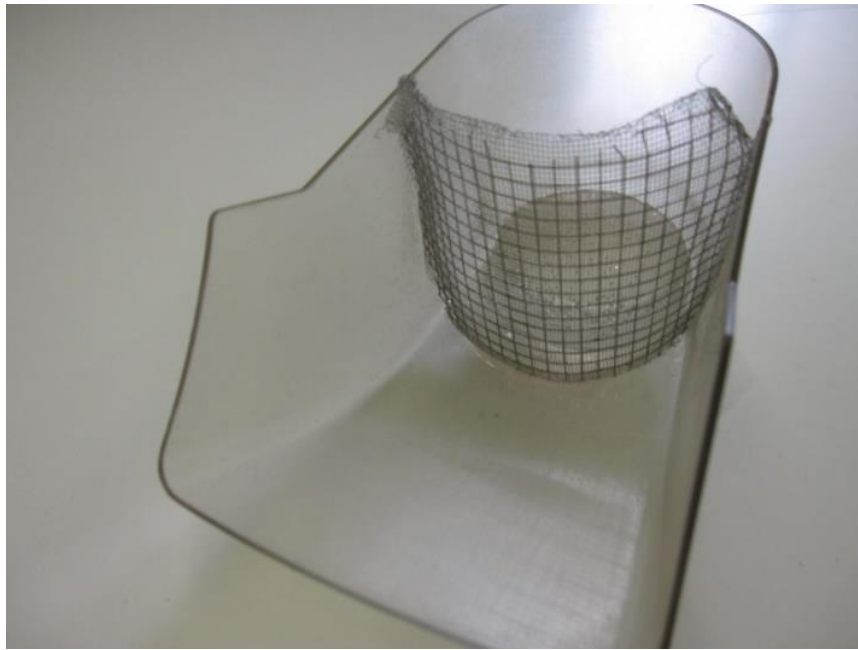
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- RIL Population
  - Sureño x Tx430
    - Sureño: white endosperm, small kernel size, good popping quality
    - Tx430: yellow endosperm, large kernel size, poor popping quality
  - 130 RILs,  $F_{12}$
- RCBD in the field with two repetitions
  - Weslaco 2012
  - Corpus Christi 2012
  - Halfway 2012

# Phenotyping of Popping Traits

# First...

- Heated air poppers for popcorn were modified
- 500 seed were counted for each RIL
- Pre-popping volume was also taken (mL)



# Next....

- Samples were heated for 2' 15"
- Two hot air poppers were blocked with each field rep
- Popped samples were poured on a 4.7mm sieve
- Kernels that fell through were considered unpopped



# Finally...

- Volume (mL) of the popped material was taken
- Un-popped material was recounted
- **Measurements a were used to calculate**
  - **Popping Efficiency (PE)**
  - **Expansion Ratio (ER)**



Popping Efficiency

Expansion Ratio

$$\frac{(500 - UPK)}{500} = PE$$

UPK = Un-popped Kernels

PE = Popping Efficiency

$$\frac{(PV)}{PE * UPV} = ER$$

PV = Popped Volume

UPV = Un-popped Volume

ER = Expansion Ratio



# Heritability of Popping Characteristics

# Statistical analysis

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- Combined analysis (Random) across locations using SAS software, broad sense heritability was calculated on an entry mean basis:

$$H^2 = \frac{\sigma_g^2}{\sigma_g^2 + \frac{\sigma_{gxe}^2}{e} + \frac{\sigma_e^2}{re}}$$

- Statistical model for combined analysis:

$Y = \text{Gen} + \text{Gen} * \text{Env} + \text{Rep}(\text{Env}) + \text{Environment} + \text{Popper}(\text{Rep} * \text{Env}) + \text{Error}$

All effects considered random

# Combined Analysis of Popping Traits

Halfway, Corpus Christi, and Weslaco TX

Source	D.F.	M.S. (ER)	M.S. (PE)
Popper(Rep*Env)	3	7.7	0.08
Rep(Env)	6	12.0	0.47
Environment	2	110.2	3.27
Genotype	124	20.7	0.15
Geno*Env	246	6.6	0.05
Error	1003	2.3	0.01

PE: C.V. = 21.951 R-Square = .755

ER: C.V. = 22.068 R-Square = .602

PE = Popping Efficiency

ER = Expansion Ratio

p < .001    p < .01    p < .05

# Entry Mean Heritability Estimates

	Heritability ( $H^2$ )
<b>Popping Efficiency</b>	0.69 (0.59 – 0.76)
<b>Expansion Ratio</b>	0.70 (0.62 – 0.77)
<b>Test Weight</b>	0.77 (0.69 – 0.82)
<b>Height</b>	0.91 (0.88 – 0.93)

# Conclusions...

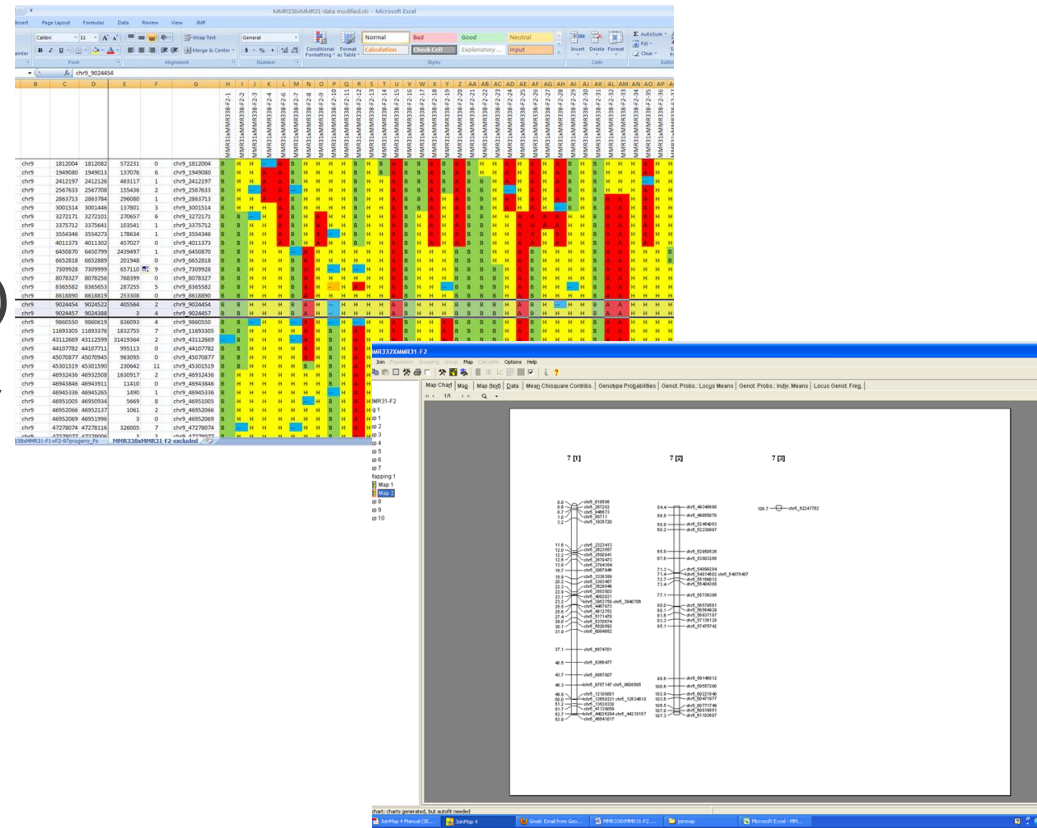
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- Popping quality traits are heritable within this population
- Improvement of popping traits in sorghum via selective breeding is likely possible

# Quantitative Trait Loci

# Genotyping and Linkage Map

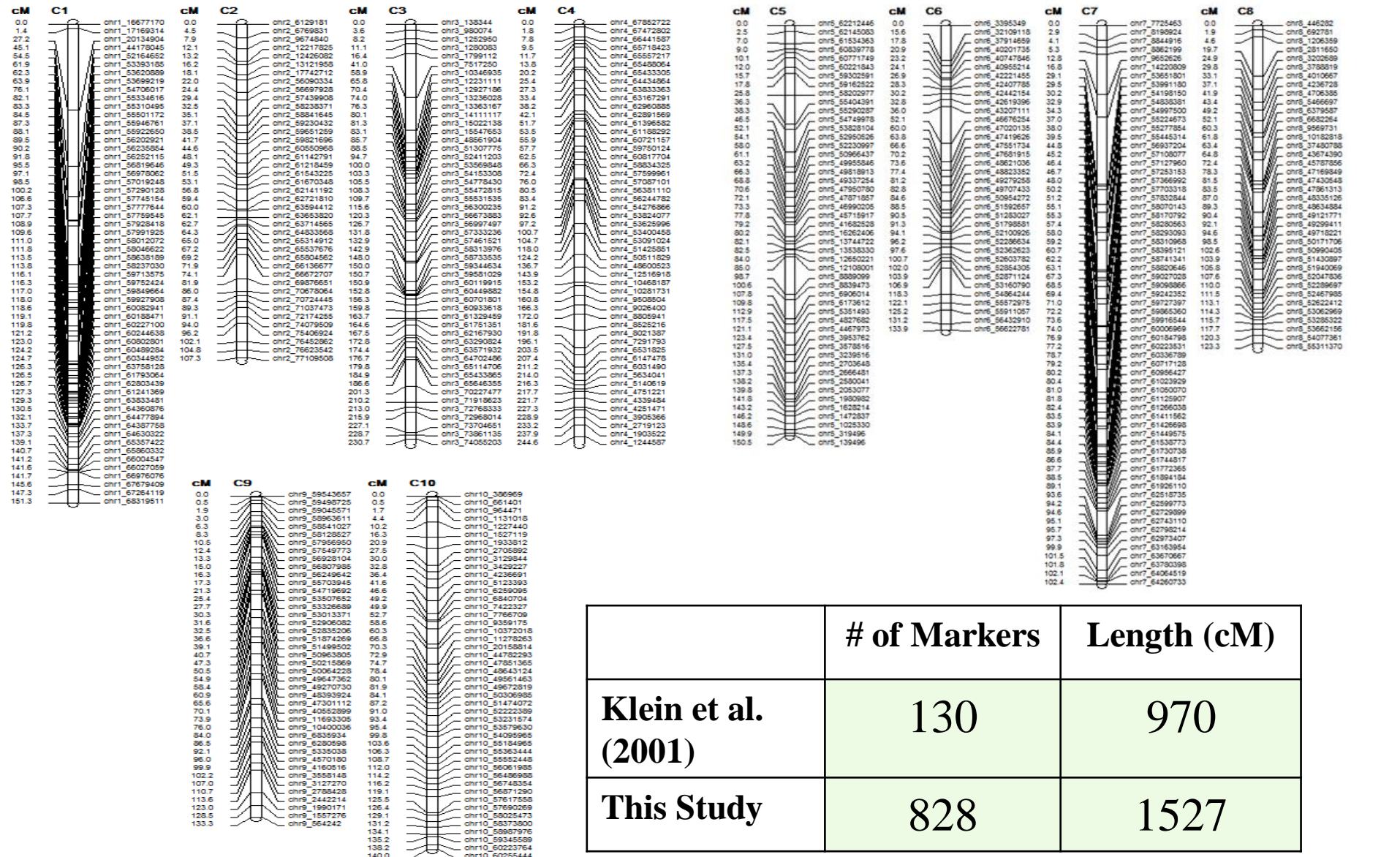
- Genotyping was conducted by the Klein laboratory using the Digital Genotyping (DG) methodology (Morishige et al. 2013)
- Genetic linkage map was constructed using JoinMap 4.0 software



Representative Pictures from Dr. Patricia Klein's laboratory: "Using Joinmap"

Morishige, D. T., Klein, P. E., Hilley, J. L., Sahraeian, S. M. E., Sharma, A., & Mullet, J. E. (2013). Digital genotyping of sorghum—a diverse plant species with a large repeat-rich genome. *BMC genomics*, *14*(1), 448.

# Linkage Map



	# of Markers	Length (cM)
<b>Klein et al. (2001)</b>	130	970
<b>This Study</b>	828	1527



# QTL for Popping Efficiency

Environments	Chro	QTL 1 LOD Interval	QTL Peak Position (cM)	QTL Peak Position (Mbp)	LOD	R2	Add. Effect
CC	5	109.3 – 119.0	115.9	5.1	2.66	0.07	-0.05
HW	1	128.7 – 130.5	129.3	63.8	3.59	0.11	0.04
HW	9	0.0 – 1.9	0.0	59.5	6.05	0.18	-0.06
WE	2	7.0 – 11.7	7.9	8.2	3.57	0.11	0.06
WE	3	70.3 – 75.3	73.0	13.4	4.28	0.13	0.09

Positive effects correspond to the Tx430 allele; Negative effects correspond to the Sureño allele.

# QTL for Expansion Ratio

<b>Environments</b>	<b>Chro</b>	<b>QTL 1 LOD Interval</b>	<b>QTL Peak Position (cM)</b>	<b>QTL Peak Position (Mbp)</b>	<b>LOD</b>	<b>R2</b>	<b>Add. Effect</b>
CC	3	85.5 – 95.0	91.5	52.7	3.49	0.11	-0.55
HW	5	66.1 – 68.4	67.0	49.7	5.23	0.15	-0.64
HW	10	49.1 – 51.0	49.9	6.4	4.25	0.13	-0.56
WE	9	11.1 – 12.9	11.9	57.8	5.17	0.15	-0.75

Positive effects correspond to the Tx430 allele; Negative effects correspond to the Sureño allele.

# QTL for Popping Characteristics

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- QTL for PE and ER were not consistent across multiple environments
- As expected, QTL for expansion ratio were all associated with the Sureño allele
- The lack of consistency of these QTL indicates that the traits are complex just as in popcorn

# Acknowledgments

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- Dr. Patricia Klein
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- Bethany Andrews
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- Brian Pfeiffer
- Lloyd Mbulwe

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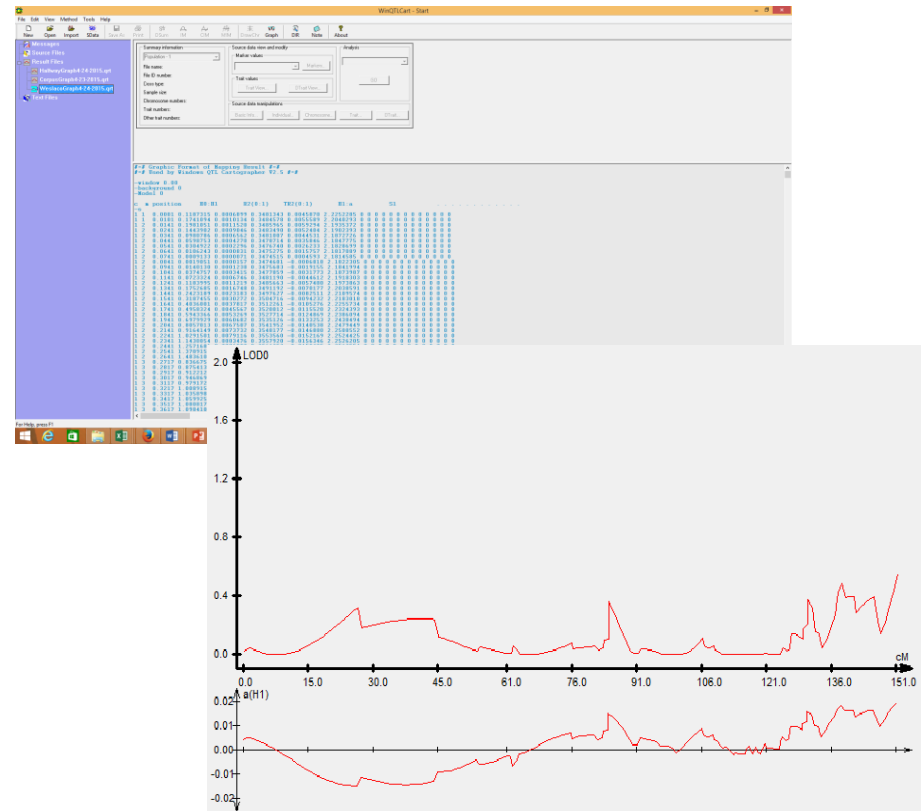
- Kathleen Hill
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- Jon Prieto
- Zachary Dickson
- Paul Hodnett

# Questions?



# QTL Mapping

- QTL were mapped using population means in WinQTL Cartographer 2.5 software
- Composite Interval Mapping with 1000 permutations at 0.05 significance level



# Population Means

	<b>Popping Efficiency (%)</b>	<b>Expansion Ratio (x : 1)</b>	<b>Kernel Diameter (mm)</b>	<b>Kernel Weight (mg)</b>	<b>Kernel Hardness (HI)</b>
<b>Sureño</b>	39.4 a	9.8 a	2.5 a	25.1 a	96.4 a
<b>Tx430</b>	44.4 a	4.8 b	2.8 b	32.2 b	69.5 b
<b>RILs</b>	51.6 a	7.7 c	2.7 a	28.5 a	77.5 b
<b>Range of RILs</b>	6.1 – 87.9	2.9 – 13.2	2.2 – 3.2	18.8 – 40.4	20.3 – 101.0

	<b>Test Weight (g/mL)</b>	<b>Plant Height (cm)</b>	<b>Flowering Date</b>	<b>Grain Color</b>	<b>Grain Mold</b>
<b>Sureño</b>	0.79 a	161.9 a	84.5 a	1.7 a	2.3 a
<b>Tx430</b>	0.69 b	106.5 b	75.8 b	7.3 b	4.9 b
<b>RILs</b>	0.76 a	137.1 c	76.5 b	4.4 c	3.8 c
<b>Range of RILs</b>	0.57 – 0.84	73.7 – 234.5	56.5 – 91.5	1.0 – 9.0	2.0 – 6.5

Means followed by the same letter are not significantly different by Tukey's test ( $p < 0.05$ )

# Pearson's Correlation Coefficients

	<b>Popping Efficiency</b>	<b>Expansion Ratio</b>
<b>Popping Eff.</b>	1.00	0.46***
<b>Expansion Ratio</b>	0.46***	1.00
<b>Kernel Hardness</b>	0.12**	0.18***
<b>Kernel Diameter</b>	0.42***	0.03
<b>Kernel Weight</b>	0.35***	-0.06
<b>Endosperm Color</b>	-0.24**	-0.22***

	<b>Popping Efficiency</b>	<b>Expansion Ratio</b>
<b>Test Weight</b>	0.13**	0.17***
<b>Grain Mold</b>	-0.16**	-0.15**
<b>Plant Height</b>	0.05	0.08*
<b>Fat</b>	-0.19***	-0.08*
<b>Starch</b>	0.15***	-0.01
<b>Protein</b>	-0.21***	0.05

\*\*\*  $p < 0.001$     \*\*  $p < 0.01$     \*  $p < 0.05$