The National Association of Plant Breeders in partnership with the Plant Breeding and Genomics Community of Practice presents

A recipe for the perfect salsa tomato

David Francis,

The Ohio State University

Format:

- Intro to the crop
- Basic botany/mating system
- Important traits
- Organization of program
- Breeding schemes
  - influenced by the number of seeds per cross, mating system, generation time...
- Selection strategy

Tomato is in the family *Solanaceae*

The flowers are bisexual, radially symmetric, and consist of 5 parts (sepals, petals, anthers). The calyx is united, at least at the base. The corolla is also united but its shape varies.

Includes:
Tomato
Potato
Eggplant(s)
Pepper(s)
Tobacco
Tomatillo
Ground Cherry
Petunia
and more!

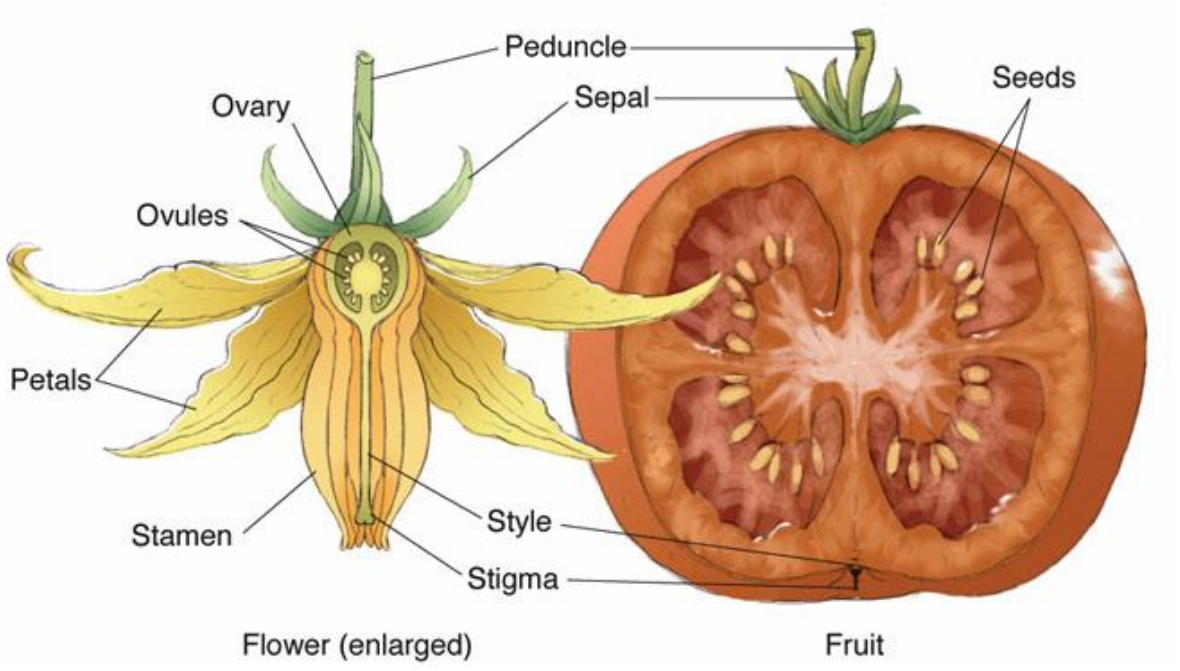


Image from:
http://www.biographixmedia.com/biology/tomato-flower-fruit.html

Important features

- Self pollinated
- Large numbers of seed per cross or self

Market Niches

- Processing
  - Whole-Peel, Paste
- Fresh-market
  - Round, Roma, Cherry
- Greenhouse
  - Round, beefsteak, cluster, cherry
  - Rootstock

Growth habit of different market classes

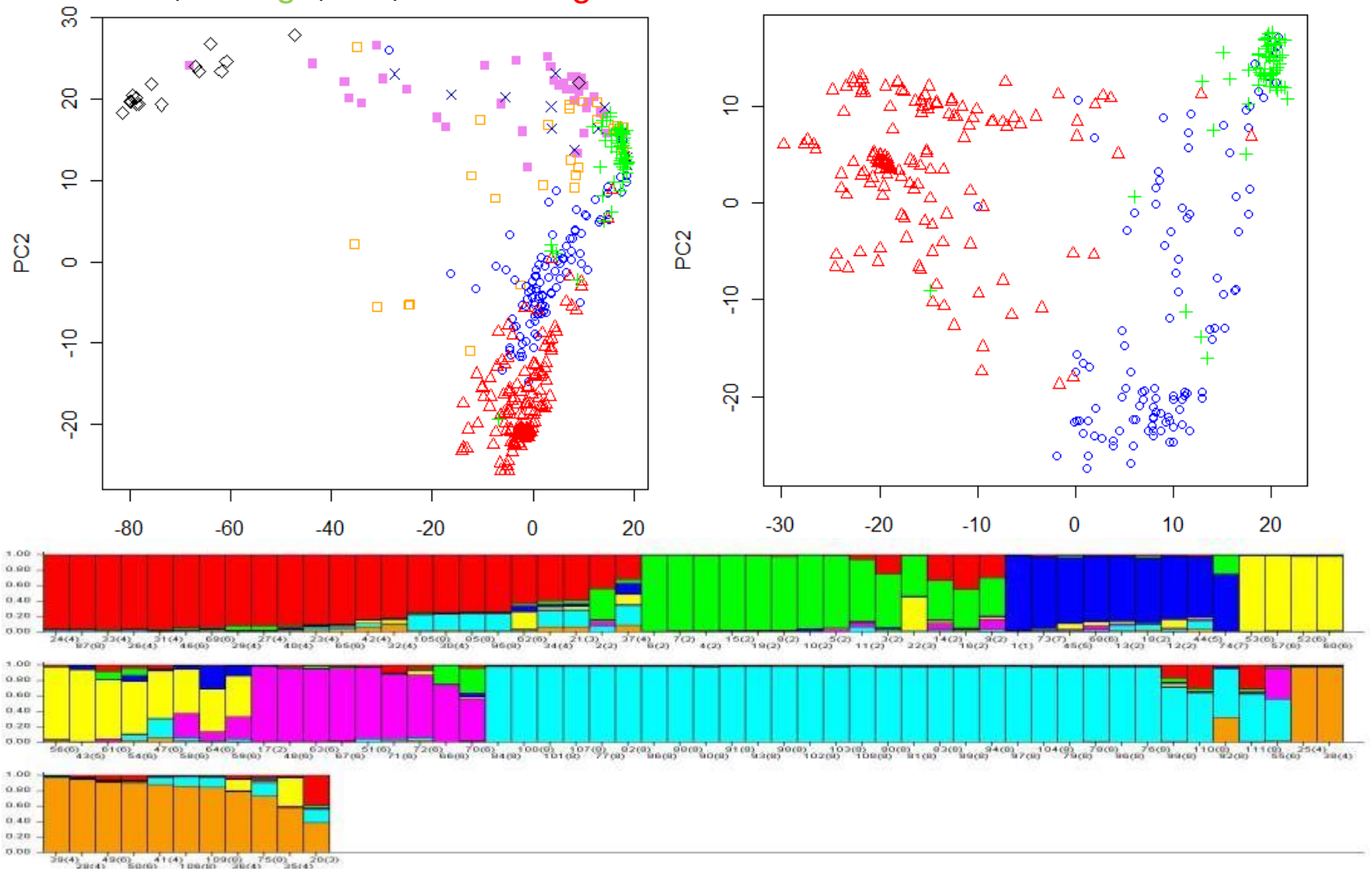

EARL DES BLACHES
1kg
1kg
1kg


REDPACK
TOMATOES
Dei Fratelli
CHOPPED
ITALIAN
TOMATOES, HERBS & OLIVE OIL
TUTTORSSO
CRUSHED TOMATOES
TUTTORSSO
PEELED TOMATOES

Market Niches have led to genetic differentiation.

(A) S. pimpinellifolium, Cherry, LR, Vintage, FM, Processing

(B) Vintage, FM, Processing



Plants vary in mating system from completely outcrossing to completely inbreeding (selfing)

Cultivated Tomato

Wild Tomato

Cultivated tomatoes are self-pollinating.

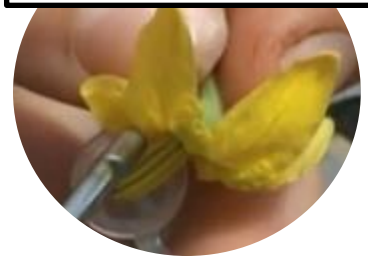
Pollen shedding often occurs before flowers open.

Self-pollinating leads to homozygosis. Inbred lines breed true.

Controlled Crosses:

Emasculation
Pollination
Tagging

Pollen collection



Emasculation

http://www.youtube.com/user/TomatoLab

Seed cleaning

Treat seed to minimize spread of seed-borne pathogens (viruses and bacteria).

Acid (HCl), Bleach, TSP, heat…

Drying tomato seeds

Packing storage

Seed saving: http://www.youtube.com/watch?v=gg8FDRa-rBQ

Large-Scale

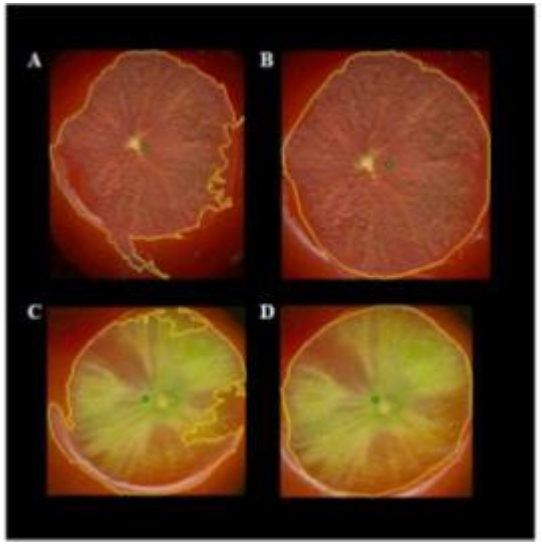
Important features

- Self pollinated
- Large numbers of seed per cross or self

Market Niches

- Processing
  - Whole-Peel, Paste
- Fresh-market
  - Round, Roma, Cherry
- Greenhouse
  - Round, beefsteak, cluster, cherry
  - Rootstock

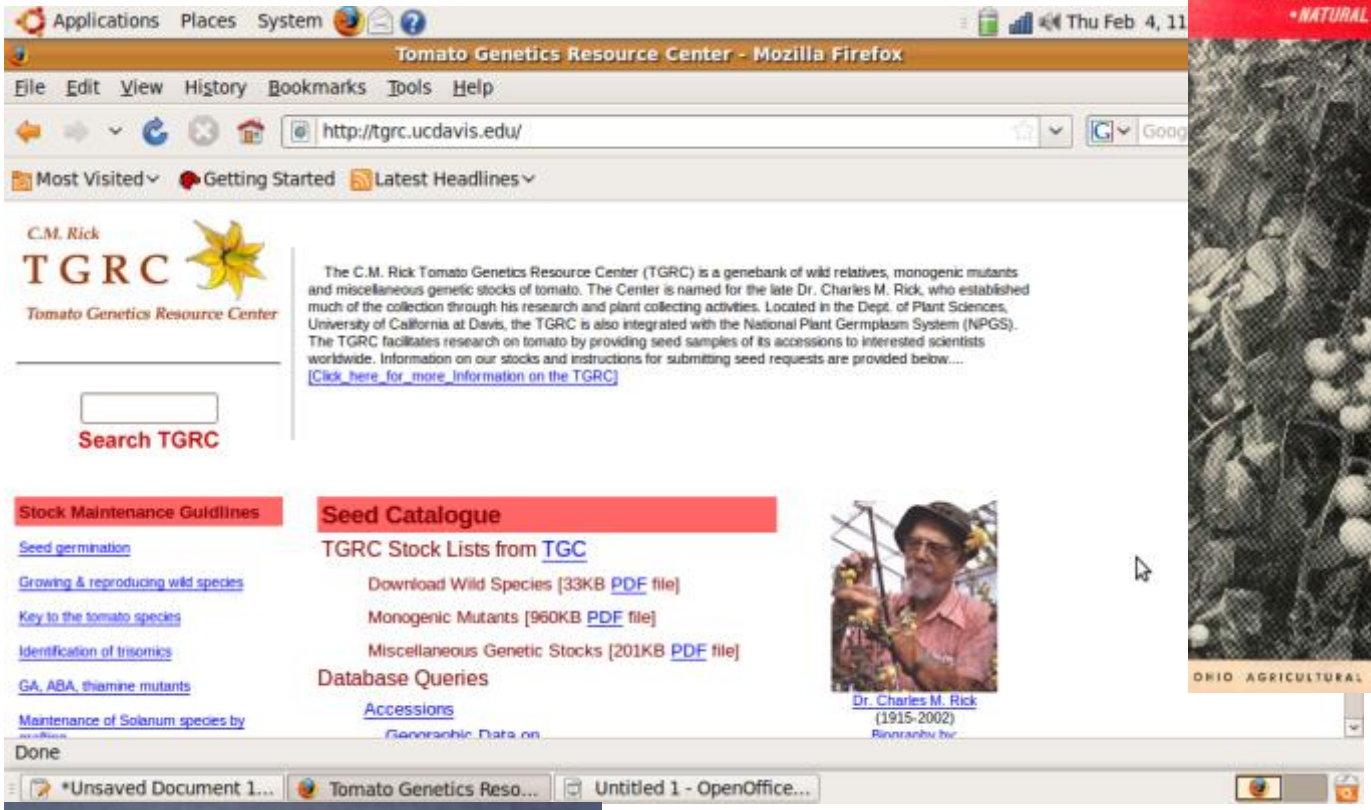
Traits – Quality and Disease Resistance

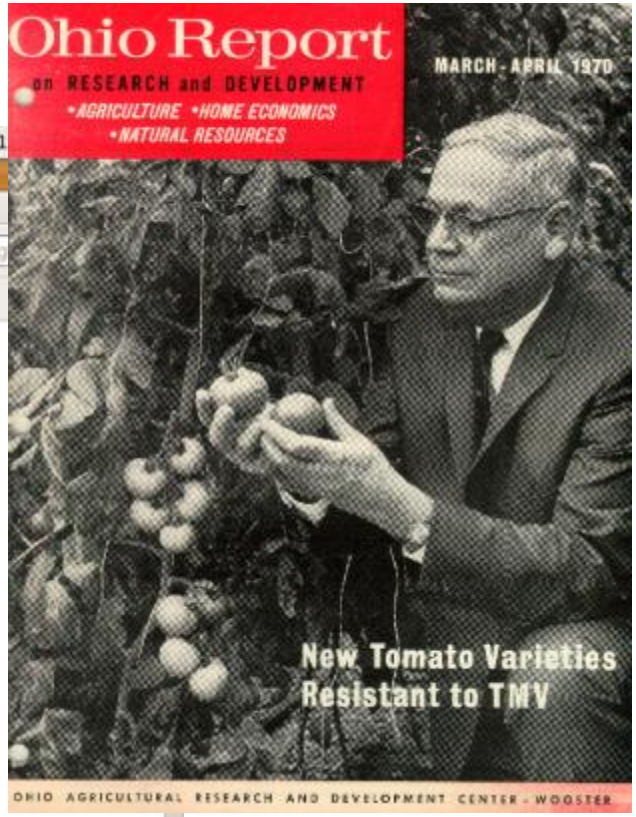


Quality for whole-peel and diced product

Bacterial Canker (*Clavibacter michiganensis*) Bacterial Spot (*Xanthomonas* species)

Sources of traits….





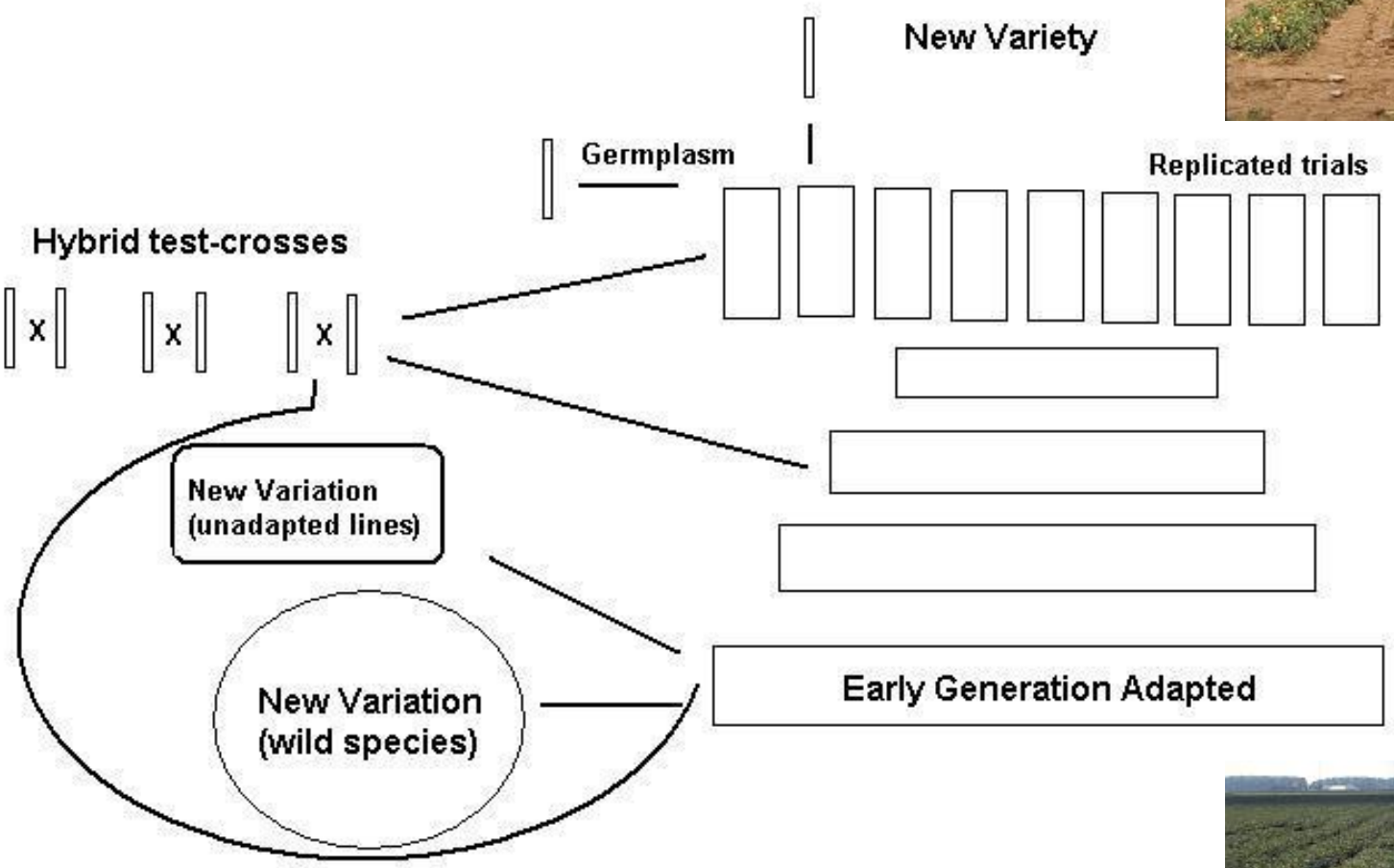
National Plant
Germplasm System
United States Department of Agriculture
Agricultural Research Service

| Home | Collections | Search GRIN | Request Germplasm | pcGRIN | Crop Germplasm Committees | Repository Home Pages | FAQs | Links |

http://tgrc.ucdavis.edu/

http://www.ars-grin.gov/npgs/

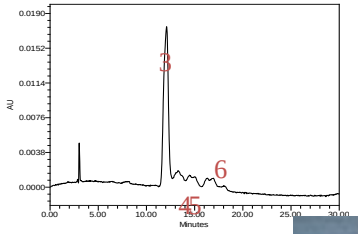
Anatomy of OSU's Tomato Breeding Program



THE OHIO AGRICULTURAL RESEARCH & DEVELOPMENT CENTER

AGRICULTURAL RESEARCH STATIONS

Anatomy of OSU's tomato breeding program



Pilot Plant

Seed Saving

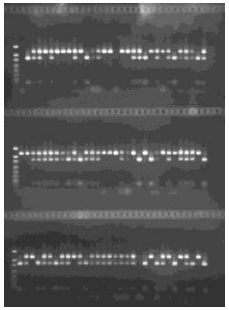
Genetics and Breeding

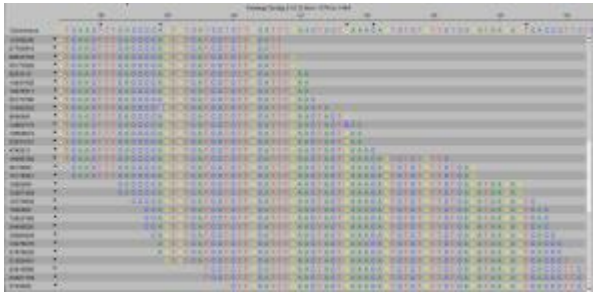
Field Testing

Pathology

Adaptation

Yield





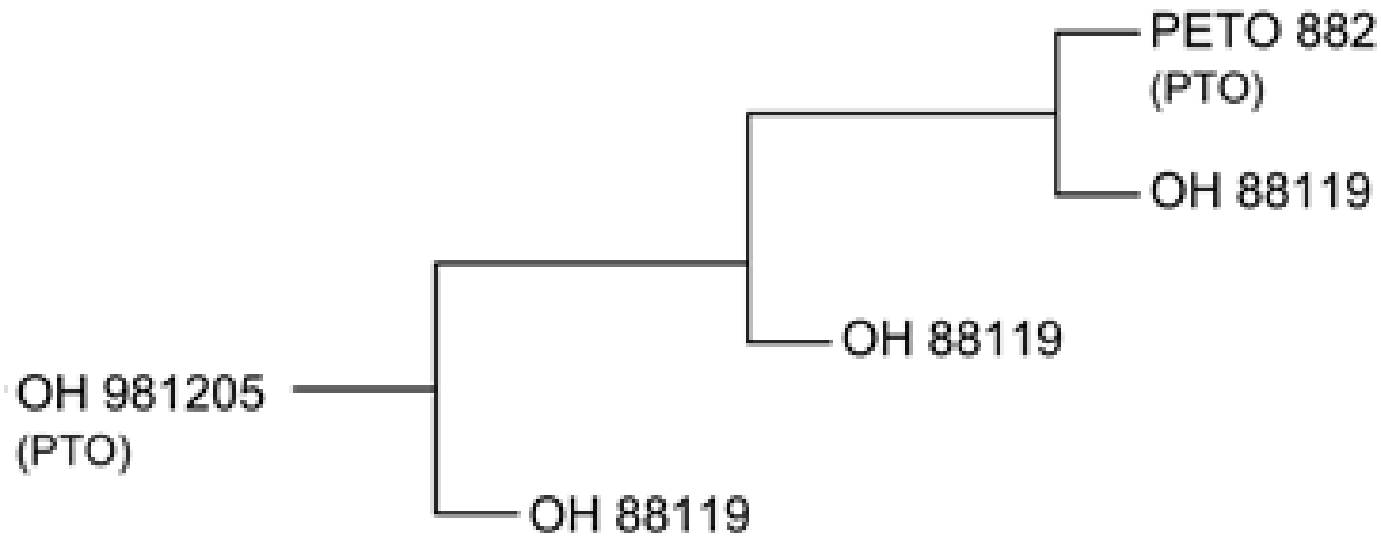
Mechanics of tomato breeding

Making crosses:
http://www.youtube.com/watch?v=acVHJBKlUIE

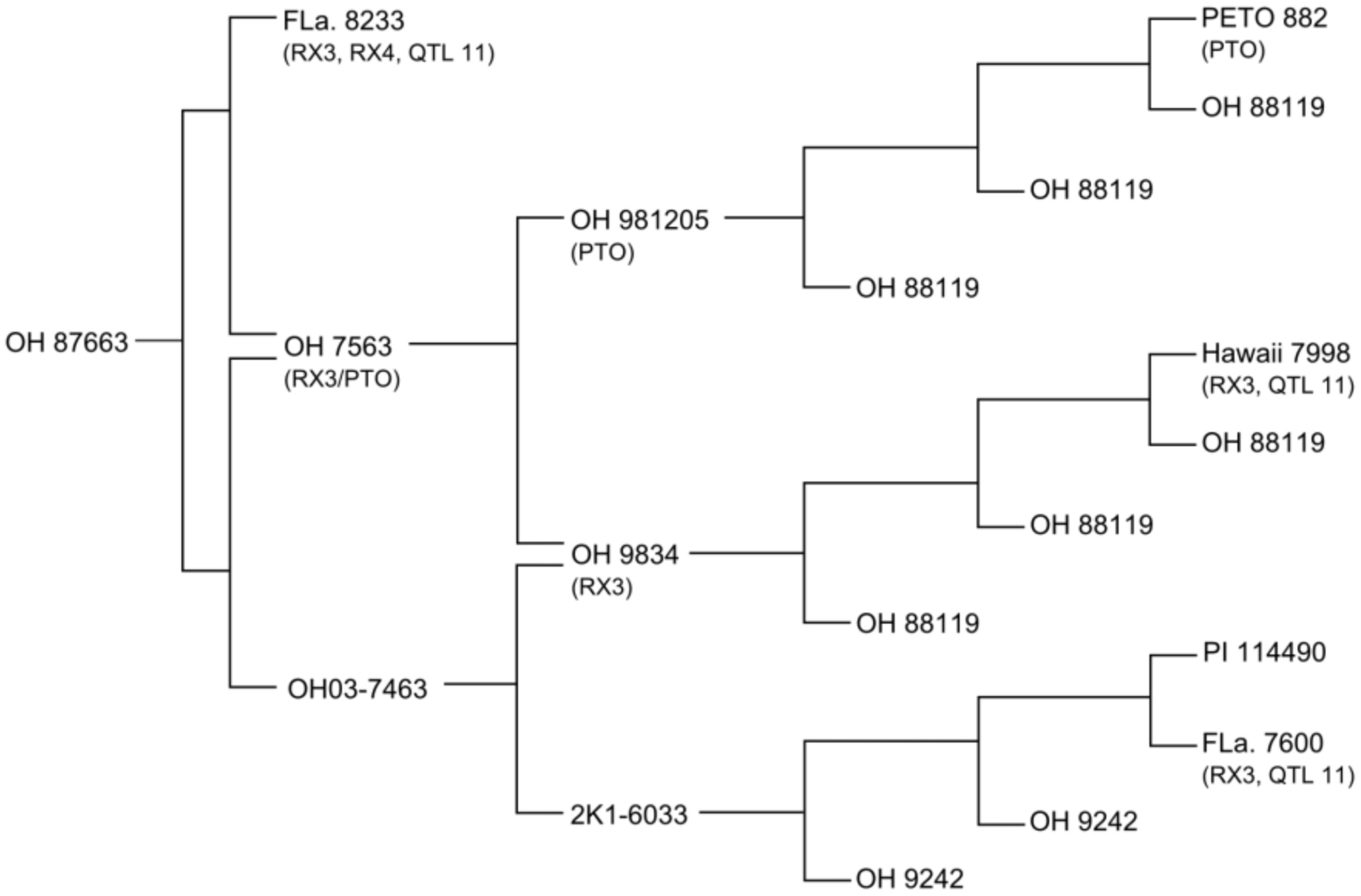
Seed saving:
http://www.youtube.com/watch?v=gg8FDRa-rBQ

Related video content:
http://www.youtube.com/user/TomatoLab?feature=watch

Backcross Breeding



Pedigree Breeding



Purpose of pedigree selection:

Combine many traits from two parents
In the long-term, pedigree selection = recurrent selection

OH 88119 – used as a parent in commercial hybrids, early with concentrated fruit set, susceptible to bacterial spot.

OH 9242 – used as a parent in commercial hybrids, excellent color, susceptible to bacterial spot.

Hawaii 7998 – resistant to bacterial spot, indeterminate plant with small fruit and poor yield.

PI 114490 – wild cherry tomato with resistance to bacterial spot

Peto 882 – processing type with resistance to bacterial speck.

Goal:
early concentrated set, excellent color, resistant to bacterial spot, resistant to bacterial speck

Resistant Selection OH87663 compared to OH88119

OH87663

OH87663 Fruit

OH88119

Plant breeders often strive to increase the efficiency of selection

- gain under selection $\Delta G = k^* \sigma_P^* h^2$
- ability to measure “G” and increase h^2
- time
- resources

Layout of field evaluations:

Follows an experimental design in order to separate the components that contribute to variation:
Between years (weather)
Within a field (soil conditions, drainage)
Between fields
Between a planting dates
Genetics

National Resource Conservation Service soil survey maps
http://websoilsurvey.nrcs.usda.gov/app/

Replication and Randomization

Randomized Complete Block and Augmented Designs (increasingly used to allow for larger populations with same resources)

Use planting date to create more environments on a single farm

Field Book

	A	B	C	D	E	F	G	H	I	J	K	L
3								PED	PED		Next	
4	Year	LOC	ROW	PLOT	GENOTYPE	PLOT SRCE	PED POP.ID	FEMALE	MALE	TRIAL	GEN	Block
5												
6												
7	2012	FRE	1	601	FG10-532	FG11-118A		OH 2641	2K8-7663	ML		1
8	2012	FRE	2	602	FG06B-432	SG11-304A		F06-1013-1	OH 2641	ML		1
9	2012	FRE	3	603	FG10-314	SG11-211A		2k4-2011-1	2k4-7517	ML		1
10	2012	FRE	4	604	H 9423	21105-6.5				ML		1
11	2012	FRE	5	605	GEM 331	331-331TO				ML		1
12	2012	FRE	6	606	FG04-167	SG11-204A		2k4-7531-1	2k4-2011-1	ML		1
13	2012	FRE	7	607	FG10-511	FG10-511B		2K8-7667	2K10-6617	ML		1
14	2012	FRE	8	608	H 3402	7690B-6				ML		1
15	2012	FRE	9	609	FG01-160	4345/4355		2K1-2054	2K1-1439	ML		1
16	2012	FRE	10	610	FG10-312	SG11-209B		2k4-2077-1	2k4-7517	ML		1
17	2012	FRE	11	611	GEM 818	818-14-06				ML		1
18	2012	FRE	12	612	FG10-505	FG10-505C		OH 981067	2k10-6617	ML		1

PED FEMALE	PED MALE	TRIAL	Next GEN	Block	Comments			
OH7814	OH987034	RIL	F7			1	1	1
OH7814	OH987034	RIL	F7			1	1	1
OH7814	OH987034	RIL	F7			1	1	1
OH7814	OH987034	RIL	F7			1	1	1
OH7814	OH987034	RIL	F7			1	1	1
OH7814	OH987034	RIL	F7			1	1	1
OH7814	OH987034	RIL	F7			1	2	1
OH7814	OH987034	RIL	F7			1	2	1
OH7814	OH987034	RIL	F7			1	2	1
OH7814	OH987034	RIL	F7			1	2	2
OH7814	OH987034	RIL	F7			1	2	2
OH7814	OH987034	RIL	F7			1	2	2
OH7814	OH987034	RIL	F7			1	2	2
						1	2	2
OH7814	OH987034	RIL	F7			1	2	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	2
						1	3	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	3
OH7814	OH987034	RIL	F7			1	3	3
OH7814	OH987034	RIL	F7			1	3	3

Field Book

	A	B	C	D	E	F	G	H	I	J	K	L
3								PED	PED		Next	
4	Year	LOC	ROW	PLOT	GENOTYPE	PLOT SRCE	PED POP.ID	FEMALE	MALE	TRIAL	GEN	Block
5												
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7	2012	FRE	1	601	FG10-532	FG11-118A		OH 2641	2K8-7663	ML		1
8	2012	FRE	2	602	FG06B-432	SG11-304A		F06-1013-1	OH 2641	ML		1
9	2012	FRE	3	603	FG10-314	SG11-211A		2k4-2011-1	2k4-7517	ML		1
10	2012	FRE	4	604	H 9423	21105-6.5				ML		1
11	2012	FRE	5	605	GEM 331	331-331TO				ML		1
12	2012	FRE	6	606	FG04-167	SG11-204A		2k4-7531-1	2k4-2011-1	ML		1
13	2012	FRE	7	607	FG10-511	FG10-511B		2K8-7667	2K10-6617	ML		1
14	2012	FRE	8	608	H 3402	7690B-6				ML		1
15	2012	FRE	9	609	FG01-160	4345/4355		2K1-2054	2K1-1439	ML		1
16	2012	FRE	10	610	FG10-312	SG11-209B		2k4-2077-1	2k4-7517	ML		1
17	2012	FRE	11	611	GEM 818	818-14-06				ML		1
18	2012	FRE	12	612	FG10-505	FG10-505C		OH 981067	2k10-6617	ML		1

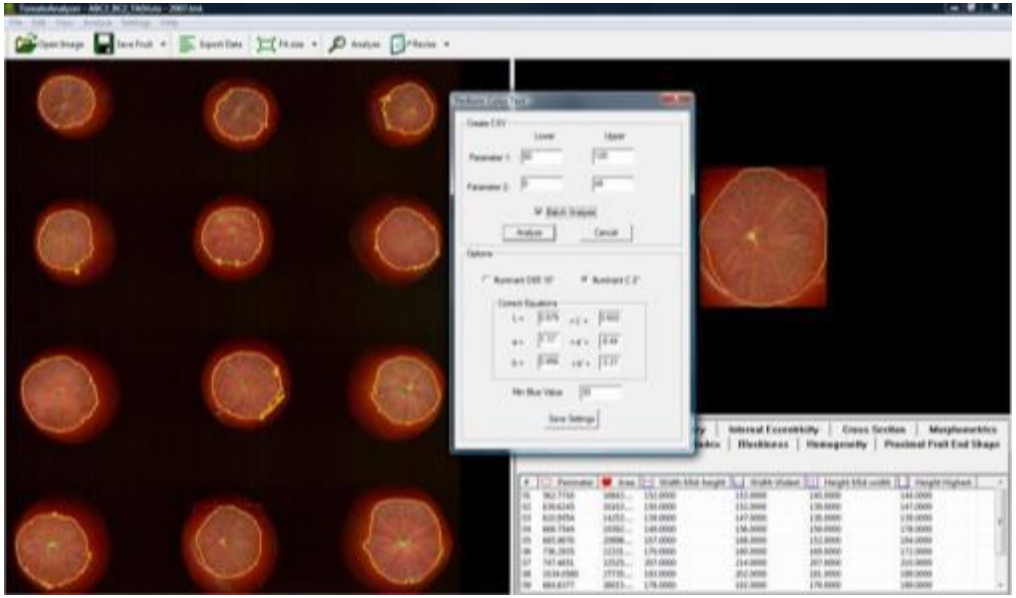
PED FEMALE	PED		Next		Comments			
OH781						1	1	1
						1	1	1
						1	1	1
						1	1	1
						1	1	1
						1	1	1
						1	2	1
						1	2	1
						1	2	1
						1	2	2
						1	2	2
						1	2	2
						1	2	2
						1	2	2
OH7						1	2	2
OH7814						1	3	2
OH7814	OH98					1	3	2
						1	3	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	2
OH7814	OH987034	RIL	F7			1	3	3
OH7814	OH987034	RIL	F7			1	3	3
OH7814	OH987034	RIL	F7			1	3	3

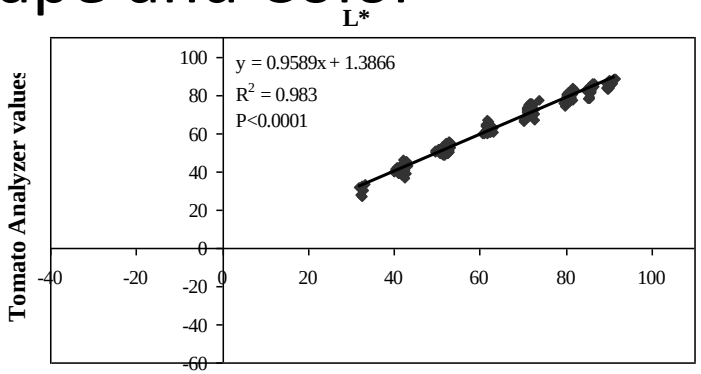
Field book contains variables for experimental design (e.g. pedigree information, location, year, row, column, and quadrant in field))

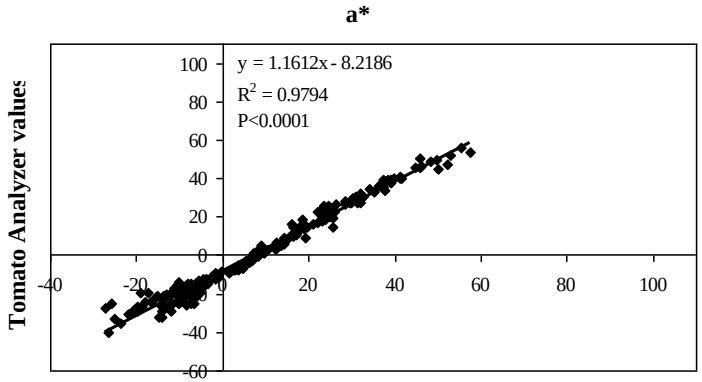
Data and workflow

Tomato Analyzer – To measure Shape and Color

(Darrigues et al., *JASHS*, 2008, **133,** 579-586)







Plot #	Plot File Name	Fruit No.	Parameter 1 (% surface w/ Hue 70-100)	Parameter 2 (% surface w/ Hue 0-50)	Avg. Red	Avg. Green	Avg. Blue	Avg. Luminosity	Avg. L	Avg. a	Avg. b
			SP:0000351	SP:0000350	SP:0000352	SP:0000355	SP:0000356	SP:0000360	SP:0000357	SP:0000358	SP:00003 9
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3801	2009_oh_3801_fruit-c.jpg	2	1.97	53.20	143.65	73.37	48.24	90.29	39.43	24.69	30.05
3801	2009_oh_3801_fruit-c.jpg	3	1.17	69.27	137.80	68.70	49.29	87.97	37.53	25.00	27.03
3801	2009_oh_3801_fruit-c.jpg	4	0.63	55.89	146.12	72.91	47.38	91.05	39.71	25.91	31.00
3801	2009_oh_3801_fruit-c.jpg	5	4.12	69.25	154.53	81.05	59.56	100.71	42.98	25.65	28.59
3801	2009_oh_3801_fruit-c.jpg	6	1.37	68.75	138.27	67.49	46.56	86.94	37.32	25.65	28.34
3801	2009_oh_3801_fruit-c.jpg	7	1.23	45.45	135.63	70.05	45.75	85.34	37.42	23.13	28.77
3801	2009_oh_3801_fruit-c.jpg	8	8.22	48.20	138.78	75.91	50.12	88.86	39.30	21.46	28.74

Field Book

	A	B	C	D	E	F	G	H	I	J	K	L
3								PED	PED		Next	
4	Year	LOC	ROW	PLOT	GENOTYPE	PLOT SRCE	PED POP.ID	FEMALE	MALE	TRIAL	GEN	Block
269	2012	FRE	1	4001	2k11-3827	2k11-3827	OH04-9411	8625-3	U265	F9	F10	1
270	2012	FRE	2	4002	2k11-3816	2k11-3816	OH04-9629	01-BR-7087x8245	03-6326	F9	F10	1
271	2012	FRE	3	4003	2k11-3854	2k11-3854	OH04-9428	8625-1	2K-3614	F9	F10	1
272	2012	FRE	4	4004	2k11-3850	2k11-3850	OH04-9624	01-BR-7087x8245	03-6326	F9	F10	1
273	2012	FRE	5	4005	2k11-3846	2k11-3846	OH04-9411	8625-3	U265	F9	F10	1
274	2012	FRE	6	4006	2k11-3848	2k11-3848	OH04-9639	01-BR-7087x8245	U265	F9	F10	1
275	2012	FRE	7	4007	2k11-3820	2k11-3820	OH04-9624	01-BR-7087x8245	03-6326	F9	F10	1

Year + PLOT = unique identifier

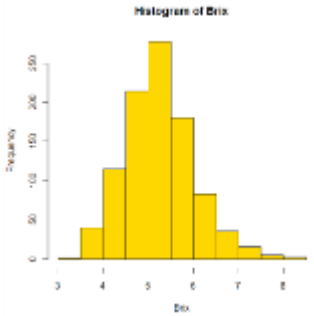
Tied to variety name “GENOTYPE” and pedigree information

Year + LOC + Block are experimental design parameters (which may be expanded in augmented designs)

Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	S
1							Wt of											
2					Harvest	Harvest	Sample				50 Ftr	Firmness						
3	Year	LOC	GENOTYPE	PLOT	Date	Total Lbs	Lug Lbs	Ripe	Green	Cull	Wt	Rating	Disease	Height	Width	Brix	pH	NaOH
8	2012	FRE	FG10-532	601	8/22/2012	157.5		127.5	22	8	6.2	4	0.5	11	33	4.7	4.41	5.95
9	2012	FRE	FG06B-432	602	8/8/2012	113		95	16	2	5.8	3	0.5	10	30	4.5	4.38	5.6
10	2012	FRE	FG10-314	603	8/22/2012	153.5		121.5	22.5	9.5	6	1	0.5	14	25	4.6	4.28	5.93
11	2012	FRE	H 9423	604	8/15/2012		36.6	33.4	1.9	1.3	6.5	1	1	14	39	5	4.24	7.53
12	2012	FRE	GEM 331	605	8/20/2012	114.5		92	11.5	11	6.3	6	1	14	35	4.6	4.32	6.81
13	2012	FRE	FG04-167	606	8/27/2012		36.7	32	3.1	1.6	8.4	0	0.5	13	23	4.4	4.19	5.78
14	2012	FRE	FG10-511	607	8/22/2012	142		117	14.5	10.5	5.8	2	1	14	41	4.7	4.41	5.41
15	2012	FRE	H 3402	608	8/27/2012		31.3	21.5	4.5	5.3	6	2	0.5	15	41	5.5	4.22	6.03
16	2012	FRE	FG01-160	609	8/29/2012		30.6	20.5	6.5	3.6	6.5	1	0.5	13	42	4.6	4.19	5.19
17	2012	FRE	FG10-312	610	8/29/2012		36.3	26.3	7.9	2.1	6.8	0	0.5	12	26	5	4.12	5.42

Phenotype Data
Distributions
ANOVA
Partitioning Variation (heritability)
BLUPs



population mean, variance, BLUP, determine selection intensity (K)

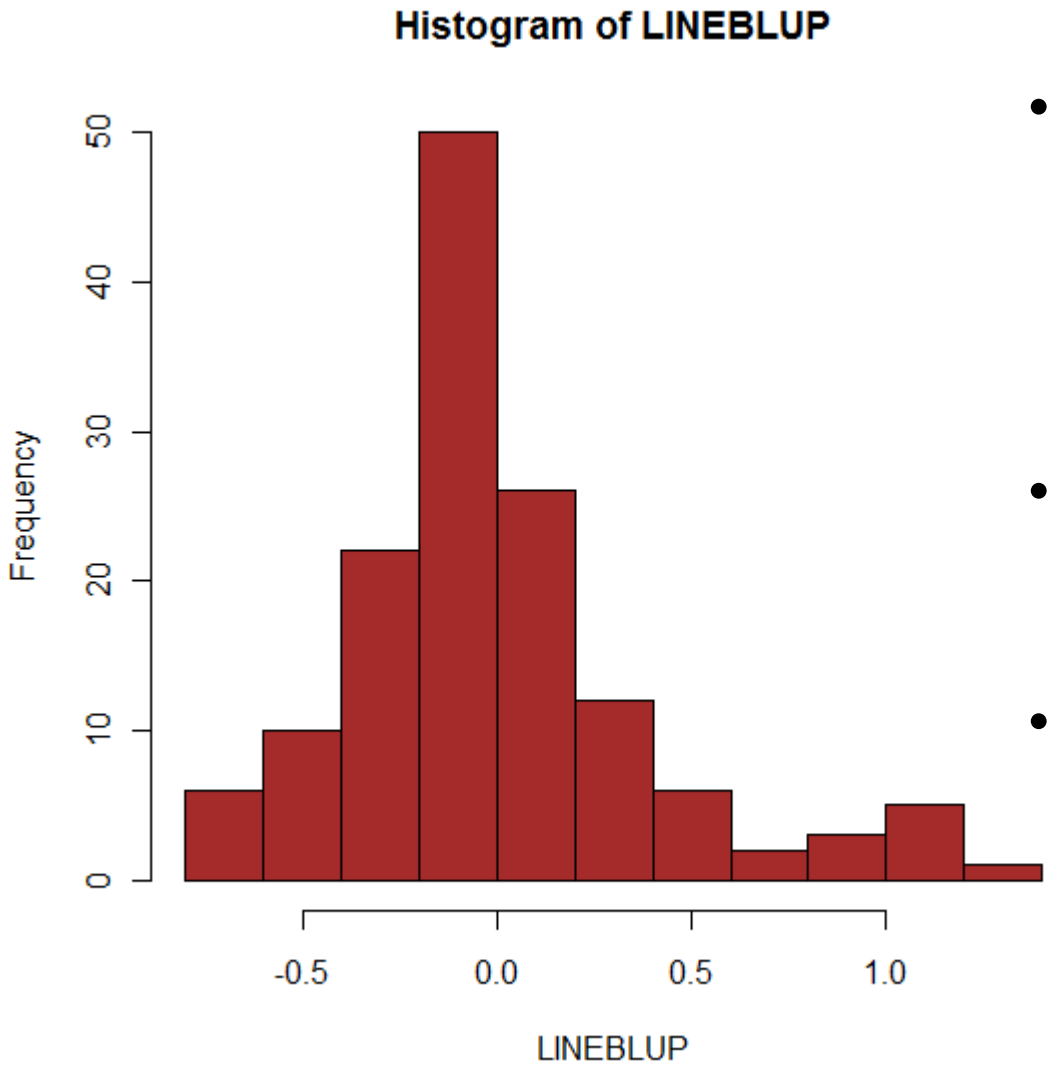
Estimate Breeding Value (Random effect)

Genotype Data
Marker Matrix

Kinship matrix

Structure
Q Matrix (PCA)

Selection: What to keep and what to throw away

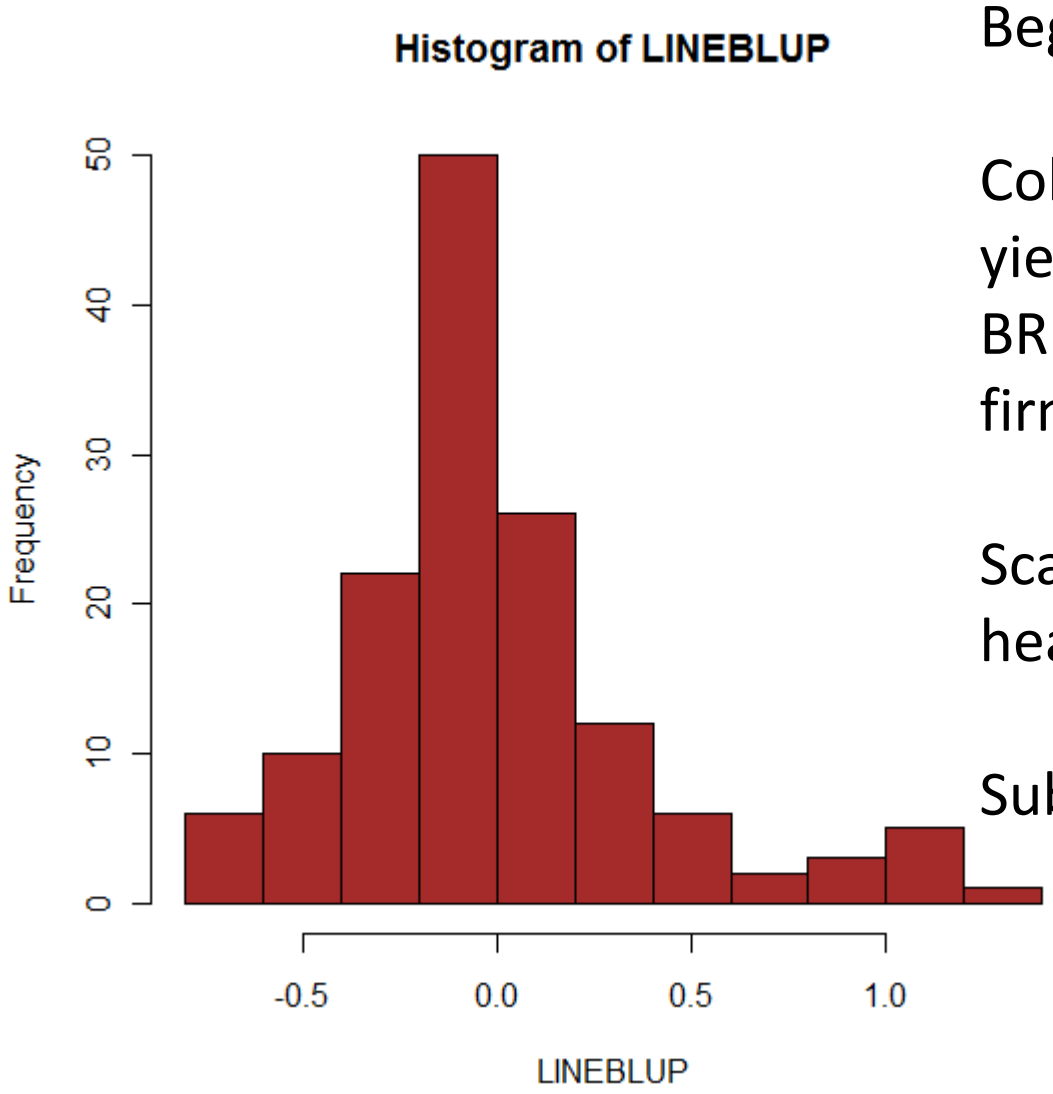


Replication at F3

- Goal: keep best individuals from the best families. (combine family-based selection and single seed descent).
- Data turn-over becomes important.

- Scaled rating of fruit size, fruit number, fruit color (internal), thickness of locule wall, firmness, vine health; analyze and go back to best families.

Selection: What to keep and what to throw away



Begin hybrid test-crosses at F4

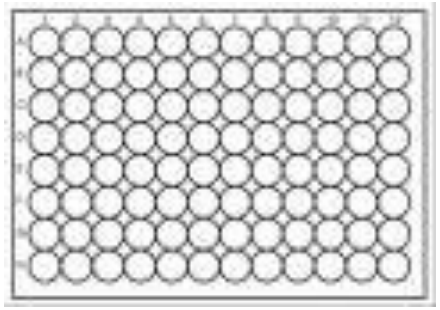
Collect objective data for yield, fruit size, fruit color, BRIX, pH, titratable acids, firmness.

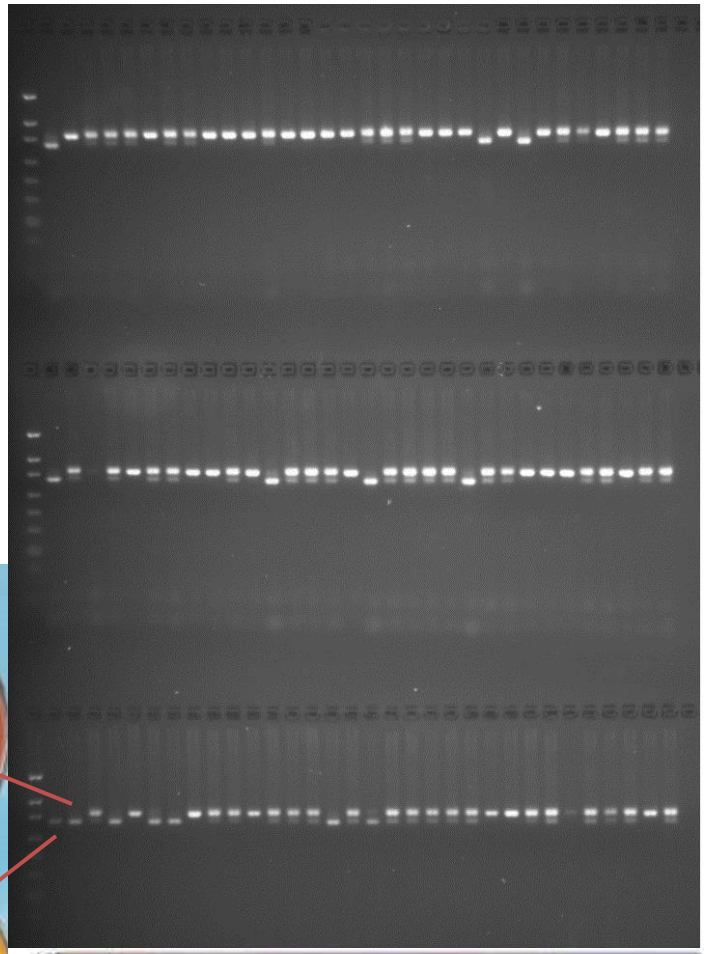
Scaled data for vine health/resistance

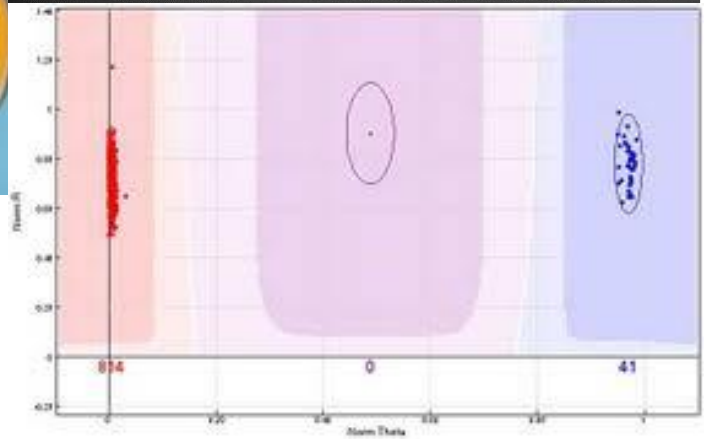
Subjective data for flavor

Marker-assisted selection

Extraction of DNA

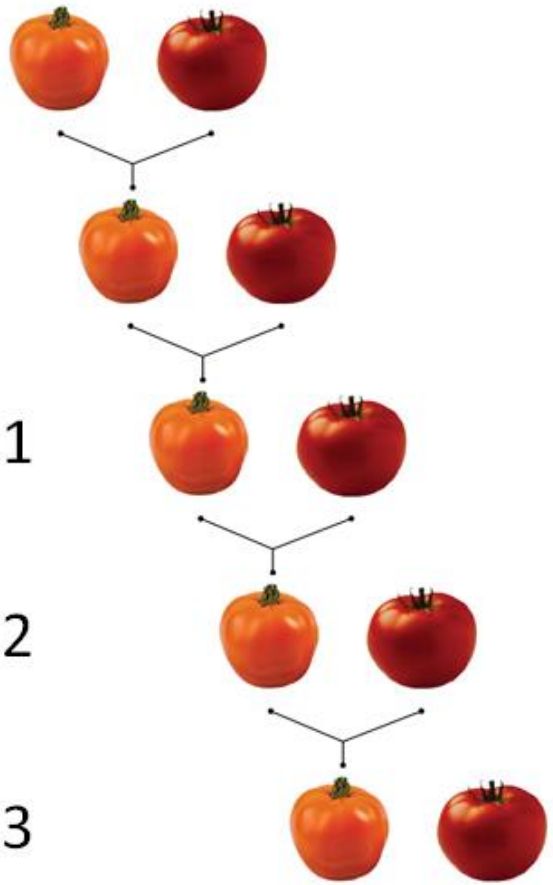




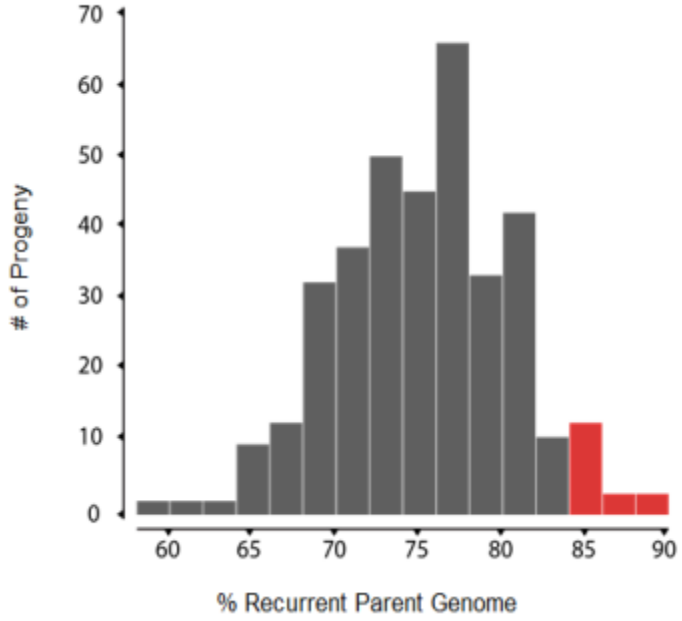


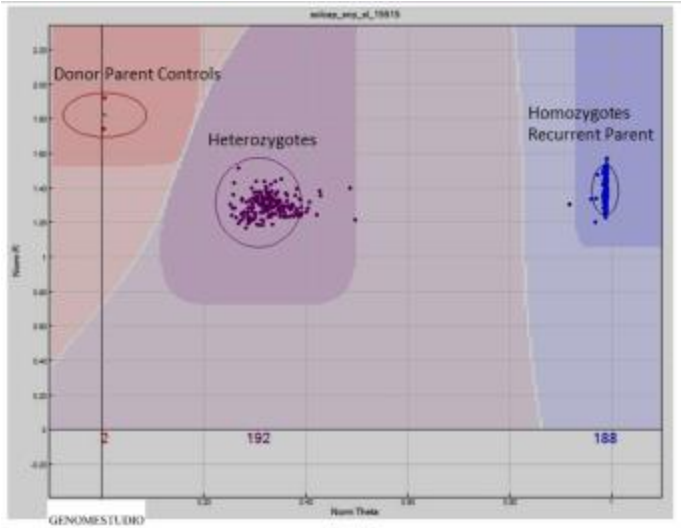
Selection based on genotype

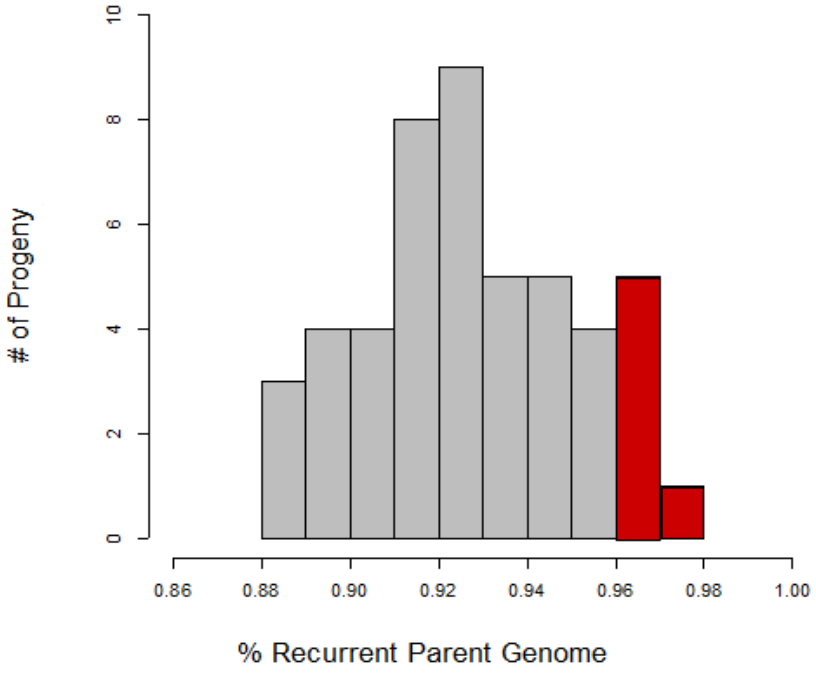
Backcross Breeding – accelerated by marker assisted background genome selection



	% Recurrent Parent
F1	50%
BC1	75%
BC2	87.5%
BC3	93.75%







DNA-based marker resources permit selection for recurrent parent genotype in order to speed back-crossing (can achieve the equivalent of BC4 at BC2)

Breeding and selection predominantly

- Backcross (including inbred-backcross and advanced-backcross)
- Pedigree
- Recurrent Selection

- Intro to the crop
- Basic botany/mating system
- Important traits
- Organization of program
- Breeding schemes
  - influenced by the number of seeds per cross, mating system, generation time...
- Selection strategy

- 2 cups coarsely diced thick-walled “roma” tomatoes (substitute can of diced tomato)
- ¼ cup chopped fresh cilantro
- 4-6 cloves fresh chopped garlic
- ½ cup chopped onion
- Jalapeno, finely chopped (alt, coat a Padron in olive oil, roast, and chop finely)
- ½ teaspoon salt
- Juice of 1 lime

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