Note:

Slide 2-49 are for 1-hr talk in the Tropical Research and Education Center

Slide 50-99 are for 1-hr talk in the Department of Horticulture

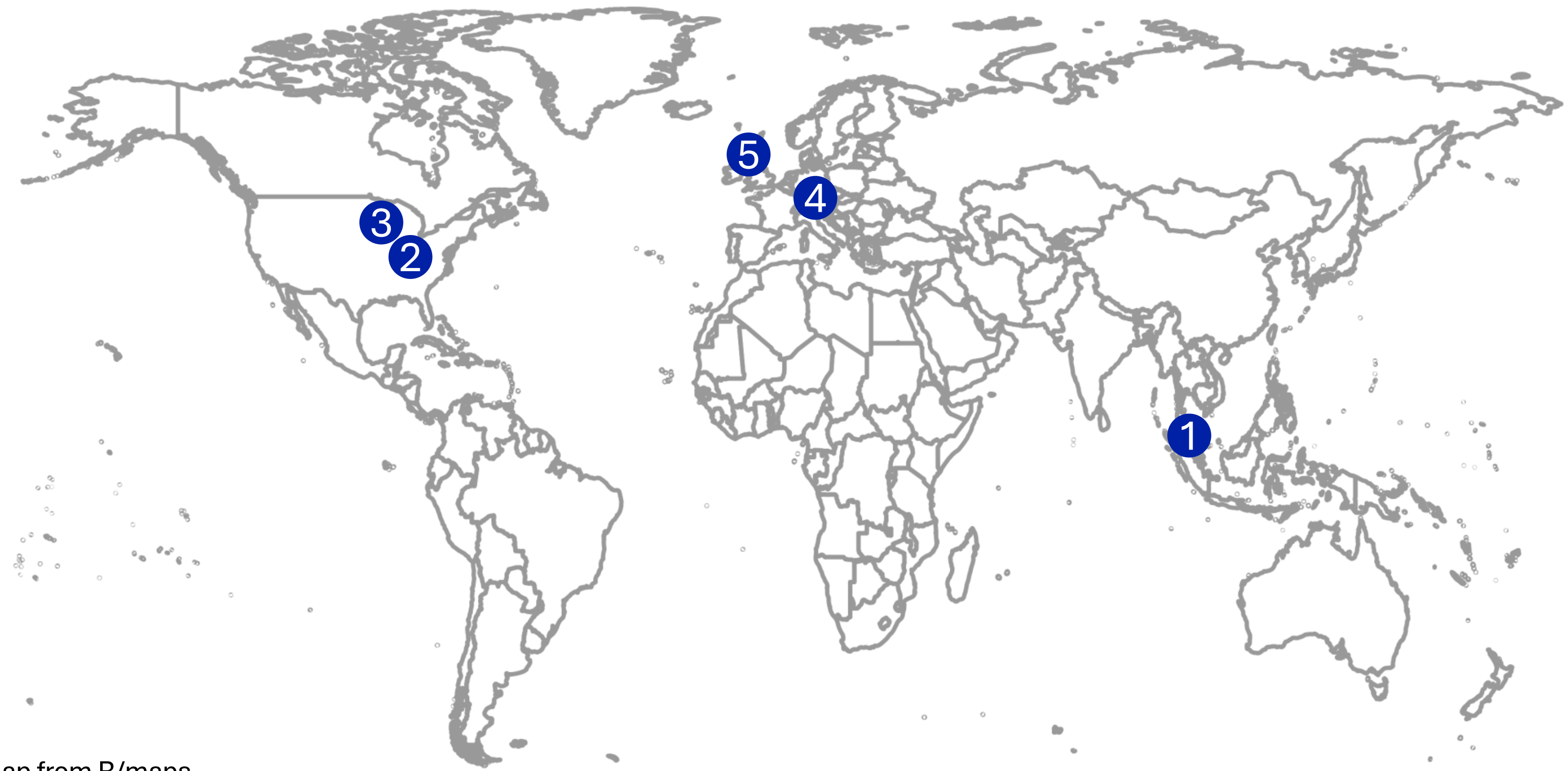
From theory to practice: applying quantitative genetics and simulation in tropical fruit crop research and breeding

CJ Yang

Homestead, FL

Nov 13, 2023

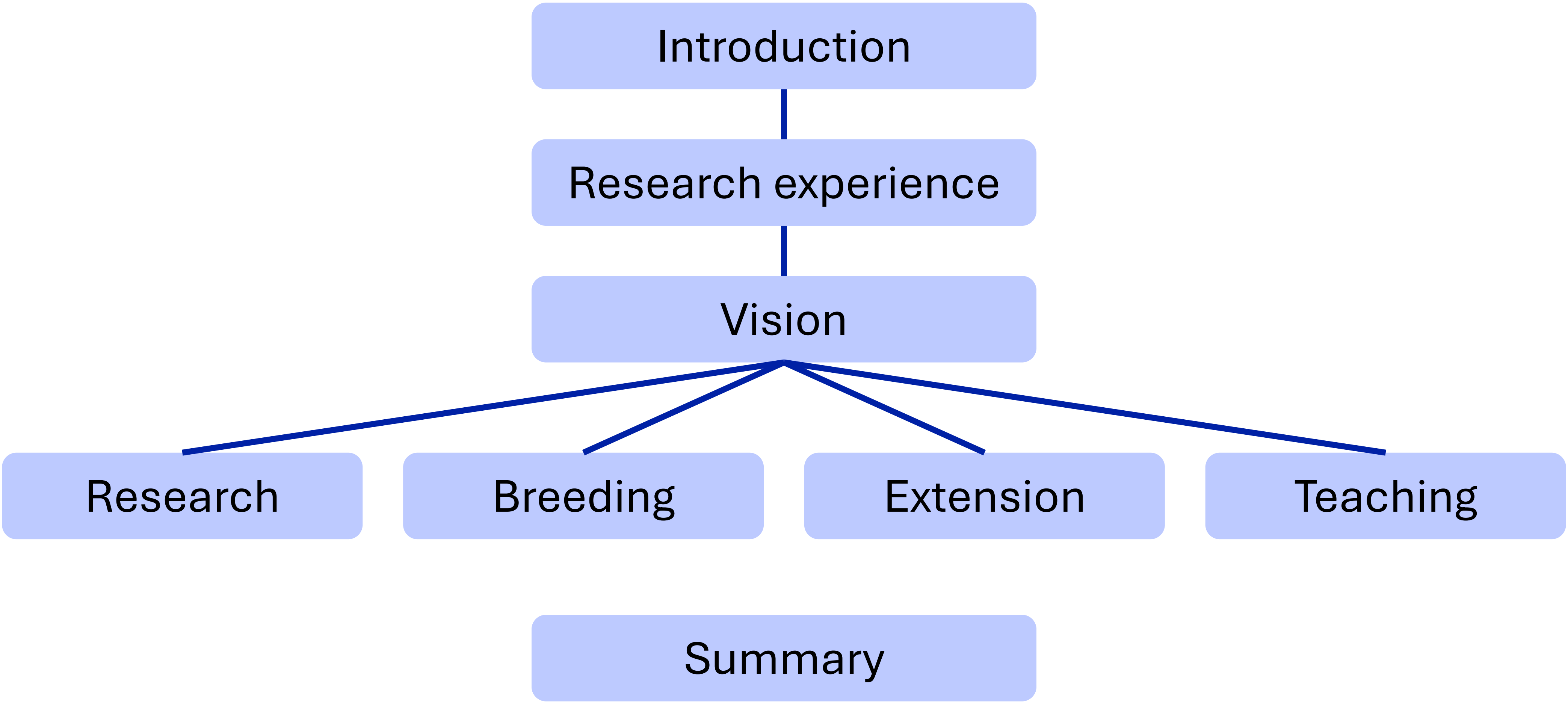
About me



Map from R/maps

1. Malaysia
2. Indiana (BSc Biotech, Maths)
3. Wisconsin (PhD Genetics)
4. Freising, DE (Postdoc)
5. Edinburgh, UK (Postdoc)

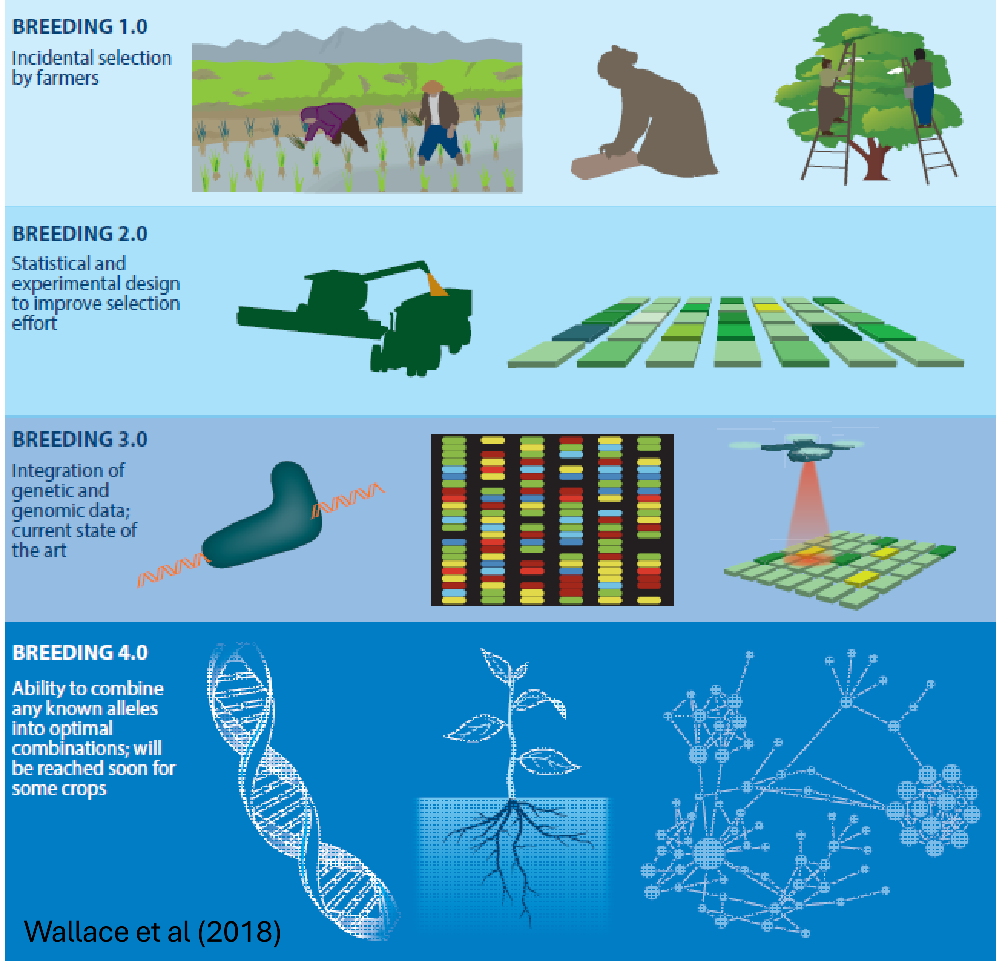
Talk outline



Introduction

Plant breeding and genetic gain

Plant Breeding



- Domestication
- Improvement

- Experimental design

- Marker assisted selection (MAS)
- Genomic/Phenomic selection (GS/PS)

- Biology-Breeding
- Functional variants
- Gene editing (GE)
- Machine learning (ML/AI)

Genetic Gain

Breeder's equation

(Lush 1937)

$$R = h^2 S$$

$$R = \frac{\sigma_g^2}{\sigma_p^2} \sigma_p i$$

$$R = \frac{\sigma_g}{\sigma_p} \sigma_g i$$

$$R = h \sigma_g i$$

Rate of genetic gain

$$\Delta R = \frac{h \sigma_g i}{t}$$

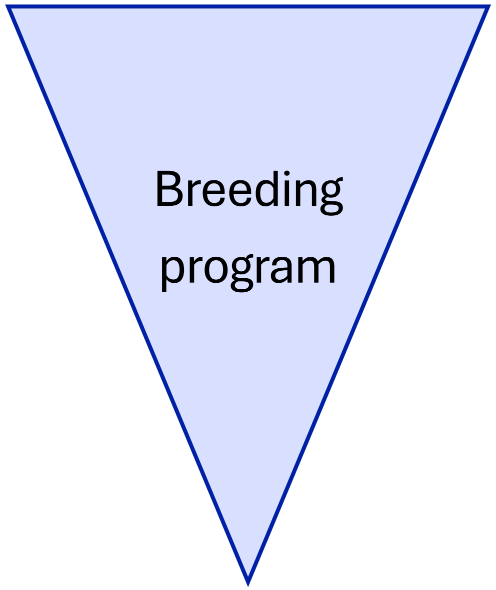
$$\Delta R = \frac{sel.accuracy \times genetic\ variation \times sel.intensity}{time}$$

Framework for quantitative genetics

Improving ΔR

$$\Delta R = \frac{sel.accuracy \times genetic\ variation \times sel.intensity}{time}$$

Population



Cultivar

- Multiparental population, mutation, pre-breeding.
- MAS, GS, GE, phenomics.
- Larger/efficient trials.
- Rapid cycling, speed breeding (SB/RGA).

Research experience

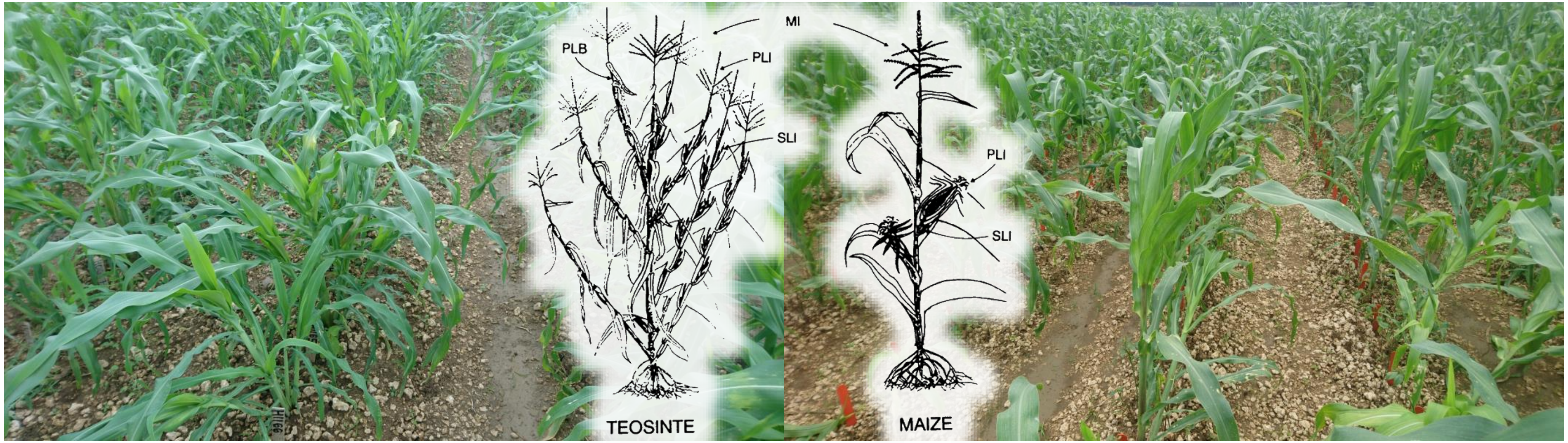
Plant breeding: a journey through time

Domestication

This earliest form of plant breeding is known as domestication, where plants were selected to be more productive, easier to harvest, or more aesthetically or gastronomically pleasing (Flint-Garcia 2013).

Domestication

This earliest form of plant breeding is known as domestication, where plants were selected to be more productive, easier to harvest, or more aesthetically or gastronomically pleasing (Flint-Garcia 2013).

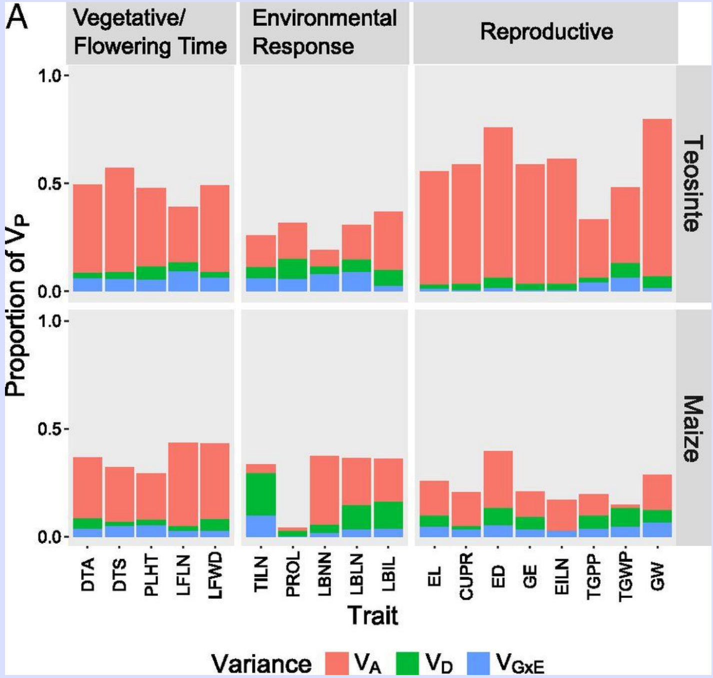


Teosinte (left) and maize (right) in Homestead, FL, 2013-2017.

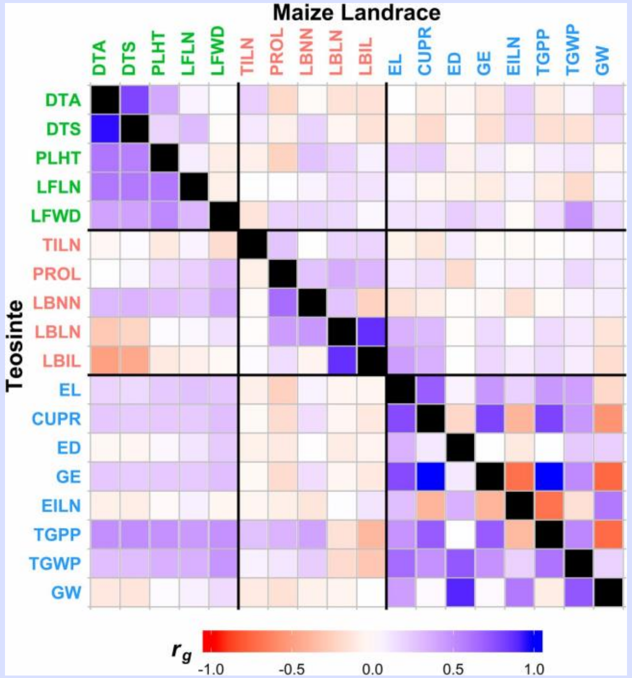
Drawings from Doebley et al (1990)

QG modelling of domestication

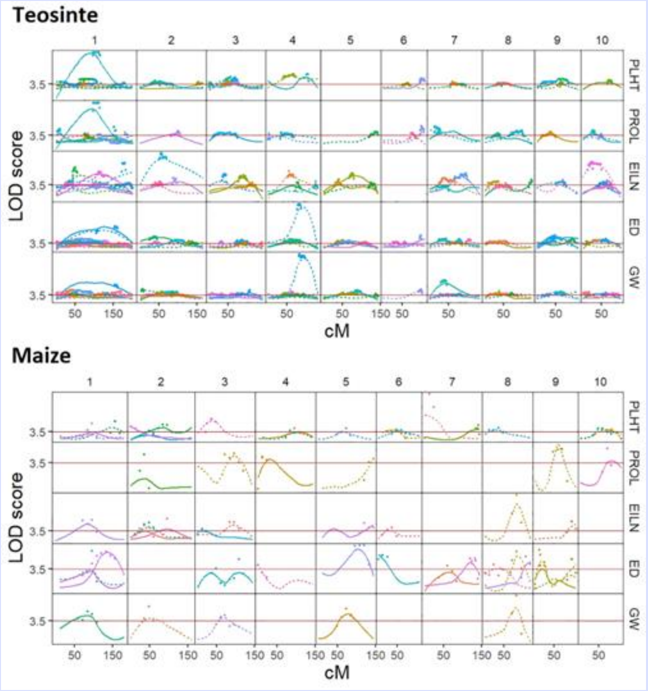
Reduction in genetic variances.



Change in genetic correlations.



Increase in inbreeding depression.
Decrease in rare deleterious alleles.

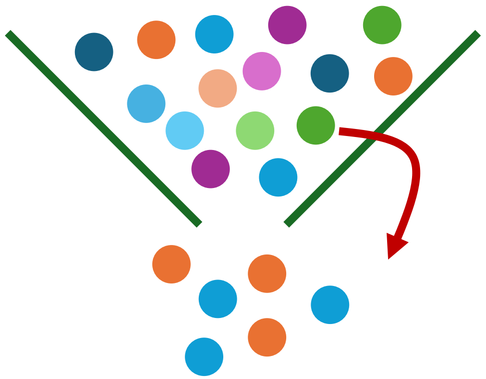


Yang et al (2019), Chen et al (2020, 2021), Samayoa et al (2021)

Shuffling genetic diversity

Domestication/Improvement

- Bottleneck
- Selection

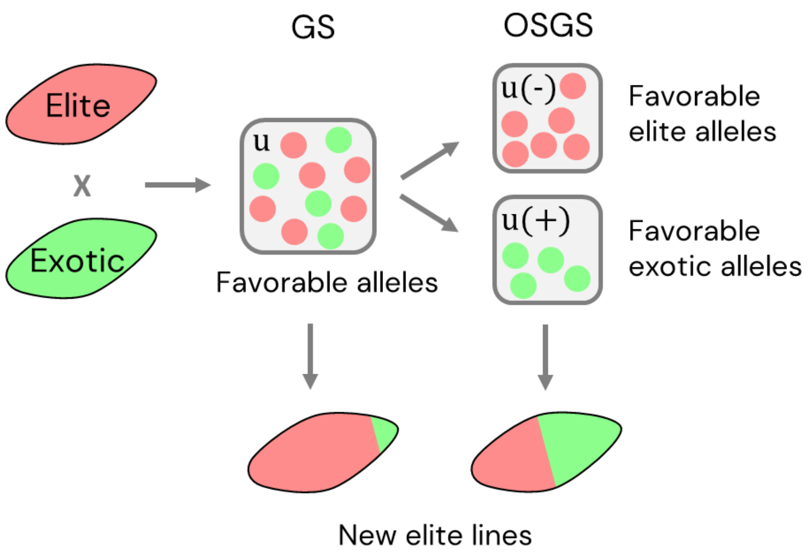


Marker assisted selection (MAS)

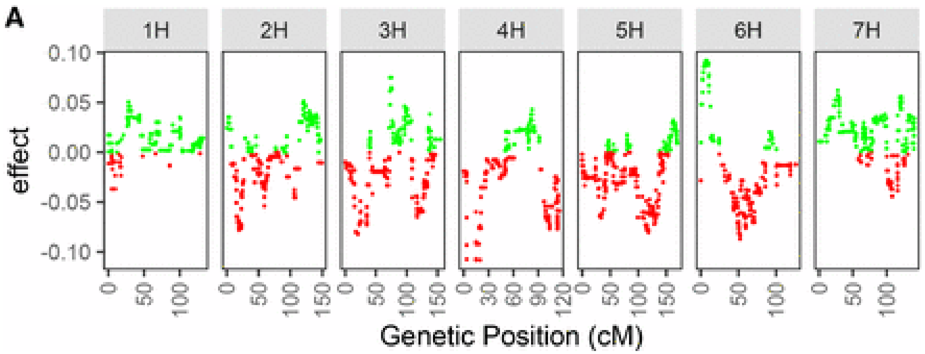
- Great for oligogenic traits.
- E.g. disease resistance.
- Inefficient for polygenic traits.

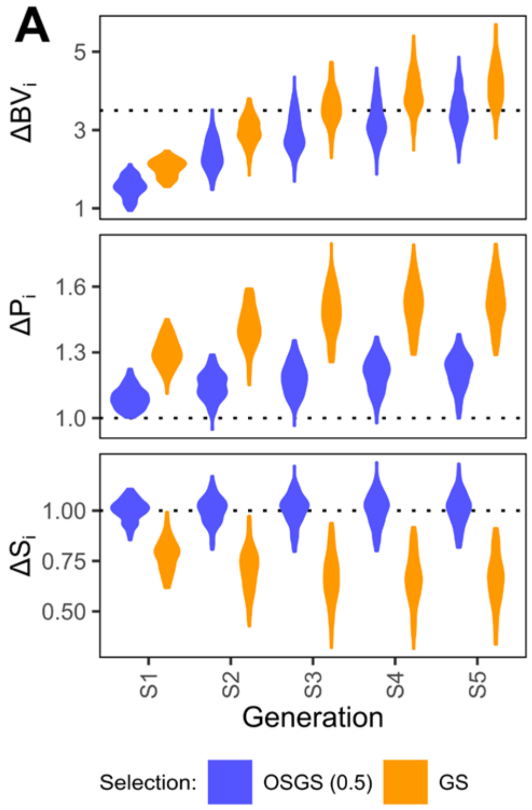
Origin specific genomic selection (OSGS)

OSGS: selection on favorable parental contribution.



Yield in a barley NAM family





Yang et al (2020)

Developing a breeding program for purslane

- Env: Vertical farm
- Trait: Omega-3 level

Table 2: Plant sources of omega-3 fatty acids (g/100 g).

Category	Fruits/vegetables	Amount (g)
Low	Avocados, California raw	0.1
	Broccoli	0.1
	Strawberries	0.1
	Cauliflower, raw	0.1
	Kale, raw	0.2
	Spinach, raw	0.1
	Peas, garden dry	0.2
	Cowpeas, dry	0.3
	Beans, navy, sprouted, cooked	0.3
	Corn, germ	0.3
Medium	Bean, common dry	0.6
	Leeks, freeze-dried, raw	0.7
	Wheat, germ	0.7
	Spirulina, dried	0.8
	Purslane	0.9
	Oat, germ	1.4
	Beachnuts	1.7
	Soybeans kernels, roasted	1.5
	Soybeans, green	3.2

Uddin et al (2014)

Identify breeding targets.

Survey variation in phenotypes, GxExM.

Engage with stakeholders.

Register varieties.

Create populations and select.

Trial in vertical farms.

Short vs long day

Fluorescent vs LED

Developing a breeding program for purslane

Royal Highland Show

Identify breeding targets.

Survey variation in phenotypes, GxExM.

Engage with stakeholders.

Register varieties.

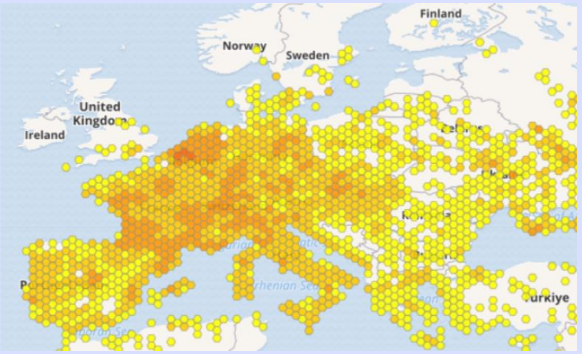
Create populations and select.

Trial in vertical farms.

Green vs golden purslane

Developing a breeding program for purslane

Sample collection



GBIF (2014-2023)

NBN Atlas

Identify breeding targets.

Survey variation in phenotypes, GxExM.

Engage with stakeholders.

Register varieties.

Create populations and select.

Trial in vertical farms.

Growth chambers

Hydroponic trials

VF – under construction

Research vision

Applying innovations from modern quantitative genetics to:

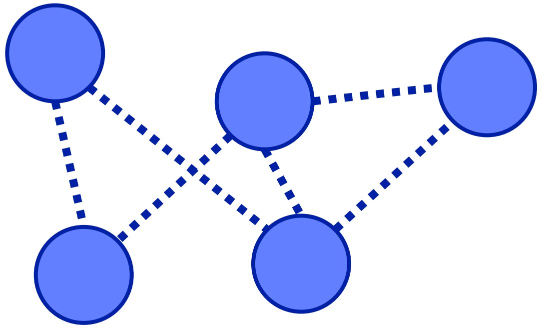
- identify ways to breed for improved tropical fruit cultivars
- understand tropical fruit genetics
- design efficient and resilient breeding programs

Area 1: Genomic selection (GS)

Genomic selection models: G-BLUP, RR-BLUP, LASSO, Bayes?, etc…

$y = Xb + g + e$ ➡ Decompose phenotype into various effects.

$g \sim N(0, K\sigma_g^2)$ ➡ Based on genotypic relationship K.



Considerations

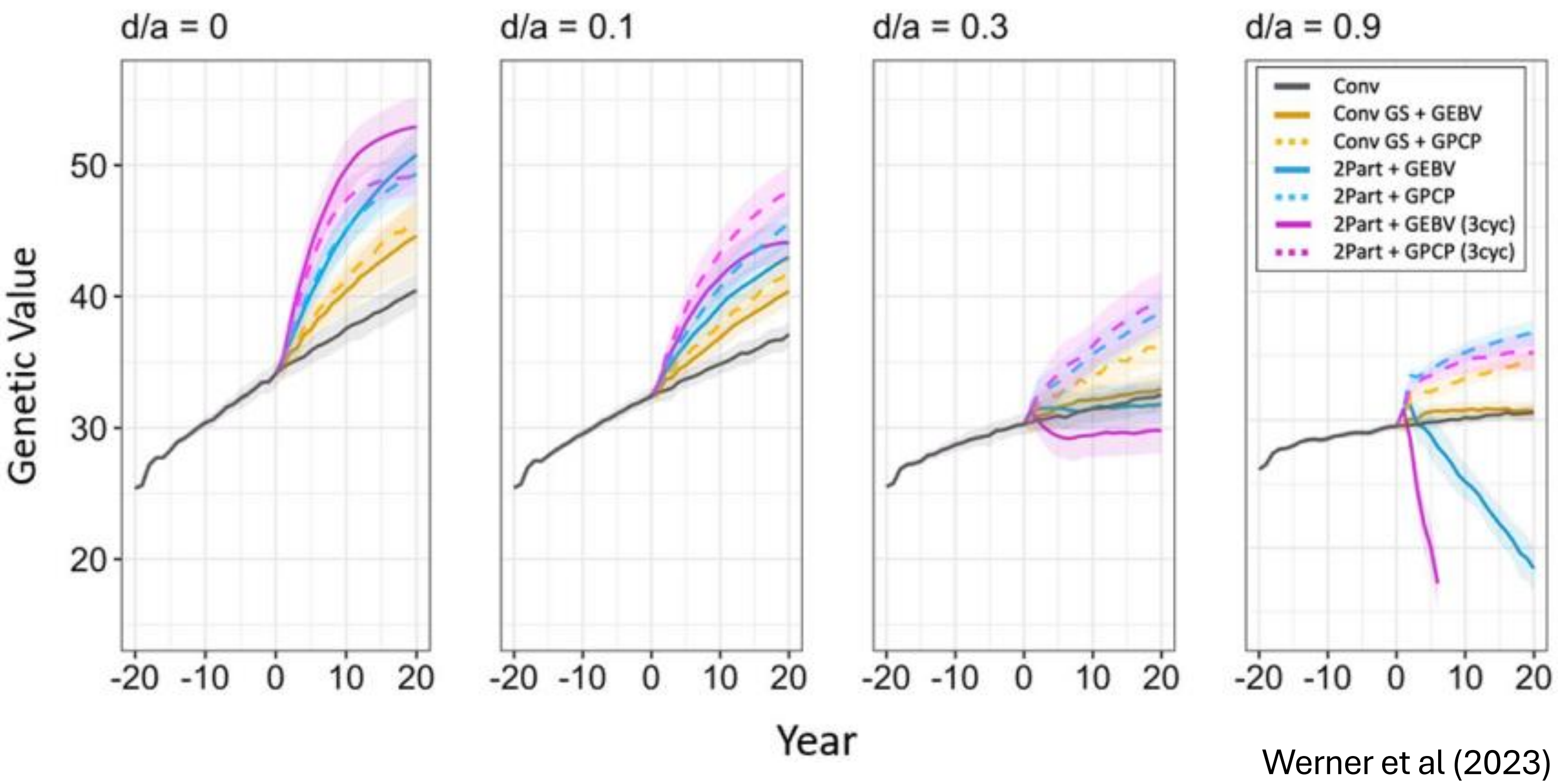
GS requires

- relationship between training and testing populations
- reliable genotyping platform
- good phenotyping quality, reasonable trials
- heritable polygenic traits
- sufficient computational power
- justifiable benefit over phenotypic selection

GS gives

- increase selection accuracy
- increase selection intensity
- reduce breeding cycle time

Clonal breeding example



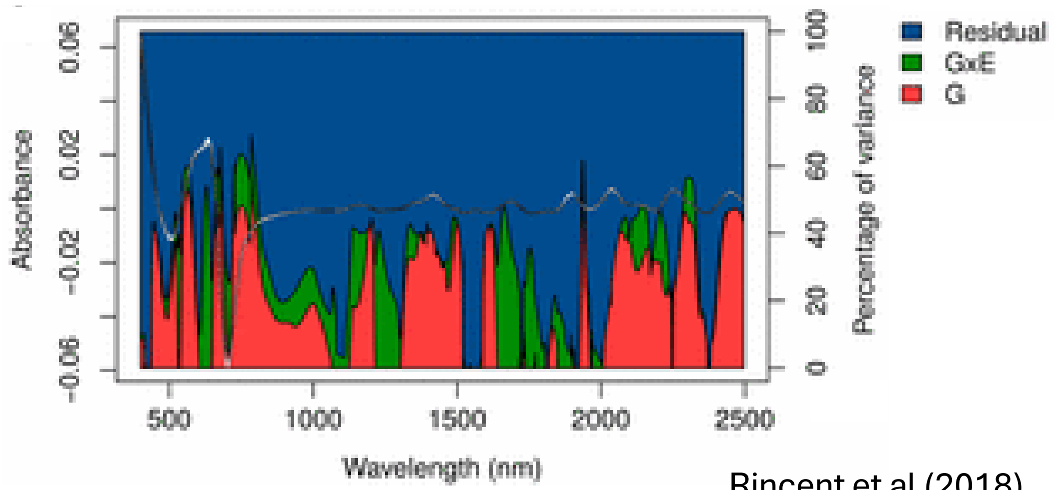
Werner et al (2023)

- Evaluate breeding strategy using simulation.
- Strawberry breeding example.
- 3 breeding programs.
- 2 parental selection methods.
- Effect of dominance on genetic gain.

Area 2: Phenomic selection (PS)

$$y = Xb + g + e \qquad g \sim N(0, K\sigma_g^2)$$

Previously, we showed the role of genotypic relationship K in the GS model.

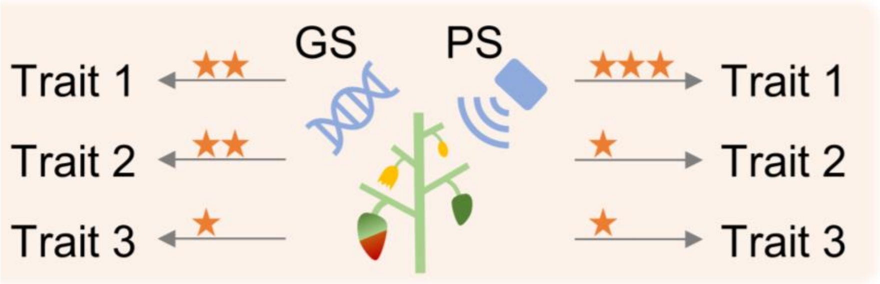


Rincent et al (2018)

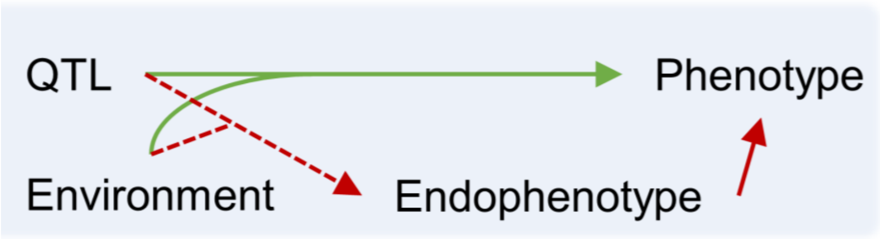
- Replace genome by phenome in calculating K.
- Phenome can be near-infrared spectra (NIRS), image data, other omics, etc.
- Part of the phenome is heritable.
- Phenome captures G x E x M.
- Phenome is cheap(?).

Opportunities in PS

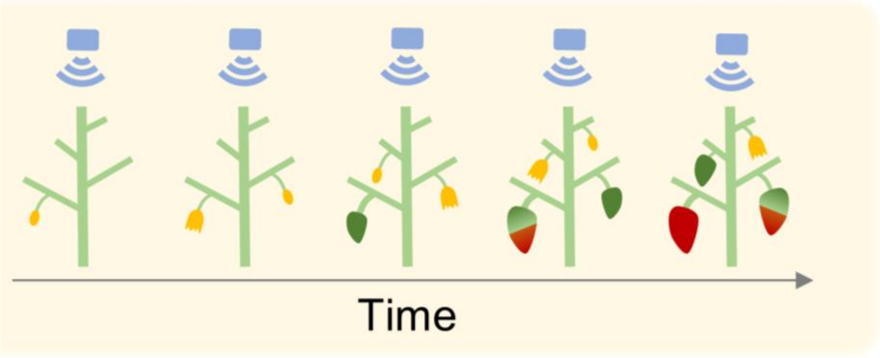
Compare GS and PS in different traits.



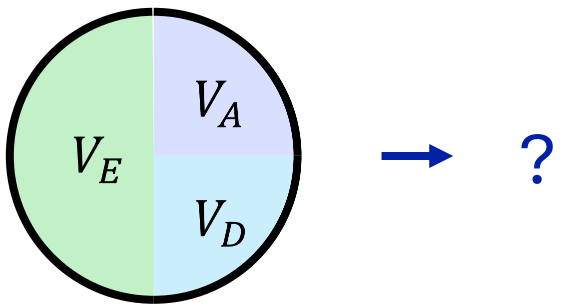
Develop methods for simulating phenome.



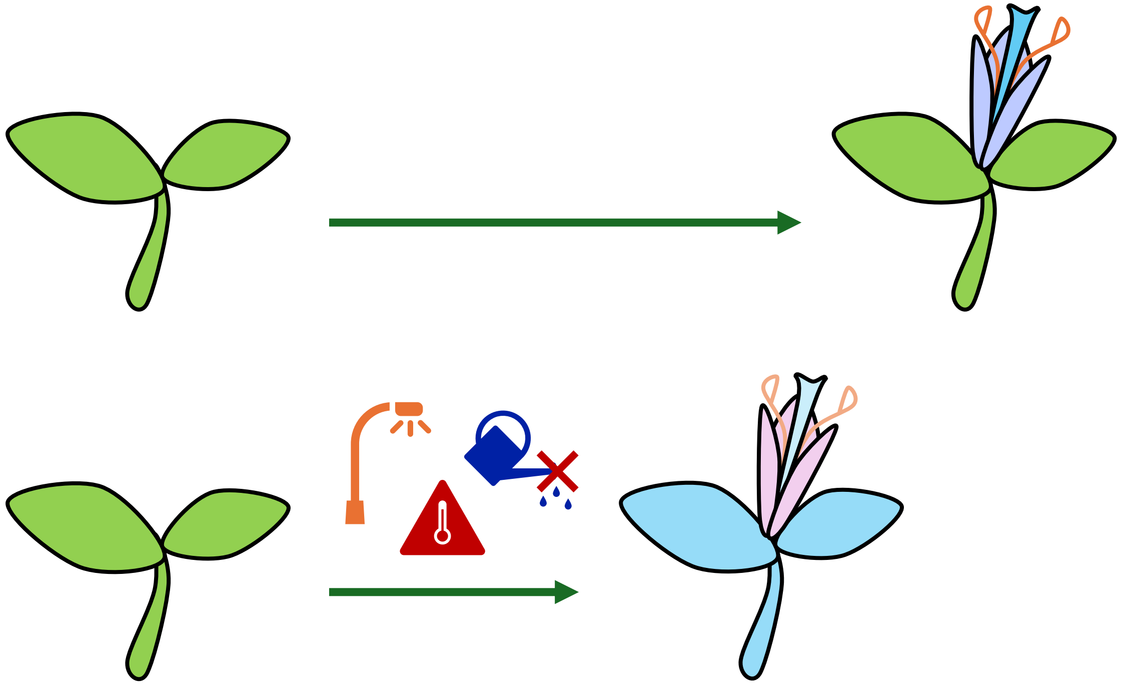
Evaluate PS across developmental time points.



Quantify "phenomic architecture" of traits.



Area 3: Speed breeding (SB)



Example in pine.

https://www.theguardian.com/environment/2022/oct/01/scotland-vertical-farming-boost-tree-stocks-hydroponics

- SB reduces the juvenile phase and breeding cycle.
- Feasible? Limited controlled environment space, short-day (photoperiod sensitive) plants.

Genetics-based SB

Standing variation

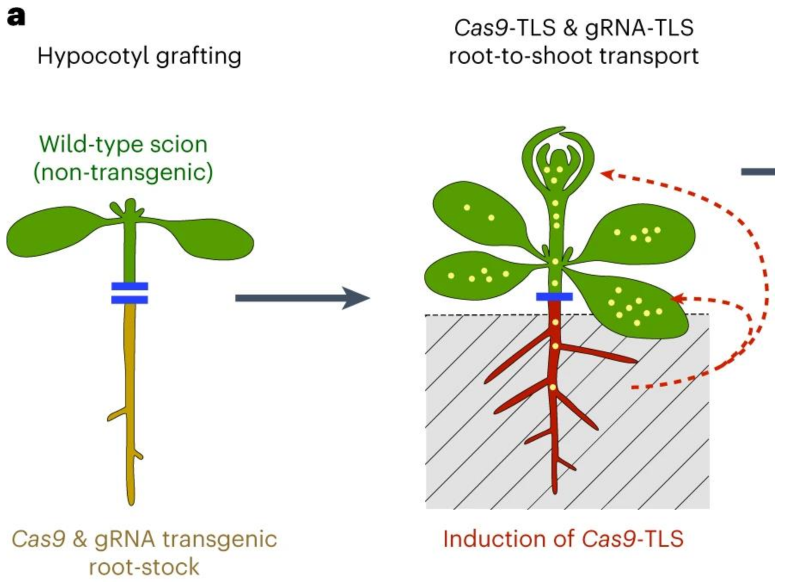
- Apply selection for early (stable) flowering and reduced photoperiod sensitivity.

Induced diversity

- Random: apply EMS mutagenesis, TILLING population.
- Targeted: comparative genomics and gene editing.

Other approach

- Graft* breeding individuals onto gene edited individuals.



Yang L et al (2023)

Collaboration and funding

Interdisciplinary projects

- Quantitative Genetics
- Simulation
- Statistics
- Bioinformatics
- Phenomics
- Crop production
- Agronomy
- Plant physiology
- Molecular biology
- Gene editing
- Plant pathology
- Entomology
- Environmental Hort
- Agroecology
- Economics

Breeding vision

- Breed for the needs of local growers.
- Ensure continuity in pre-existing breeding programs.
- Identify opportunities for improvement (evidence-based).

Tropical fruits

Banana

Carambola

Longan

Papaya

Passion fruit

Sapodilla

Pitaya

Avocado

https://commons.wikimedia.org/wiki/
File:Avacado_on_tree_(closeup).JPG

Mango

https://commons.wikimedia.org/wiki/
File:Mango_%27Julie%27_Fruits.jpg

Lychee

https://commons.wikimedia.org/wiki/
File:Litchi_chinensis_fruits.JPG

Guava

https://commons.wikimedia.org/wiki/
File:Guava_Fruit.jpg

Mamey sapote

https://commons.wikimedia.org/wiki/
File:Mamey.jpg

Sugar apple

https://commons.wikimedia.org/wiki/
File:Sugar_apple_on_tree.jpg

Vanilla

https://commons.wikimedia.org/wiki/Fil
e:Vanilla_planifolia_(6998639597).jpg

Production data

UF | IFAS Extension UNIVERSITY of FLORIDA — MIAMI-DADE COUNTY

Tropical Fruit Acreage in Florida

Jonathan H. Crane, UF/IFAS TREC and Jeff Wasielewski, UF/IFAS Extension Miami-Dade County

Common Name	Scientific Name	Miami-Dade County	Other Counties in FL
Atemoya	*Annona cherimola x A. squamosa*	Limited	Limited
Avocado	*Persea americana*	6,600	55
Banana	*Musa* hybrids	510	50
Caimito (star apple)	*Chyrsophyllum cainito*	10	1
Canistel (egg fruit)	*Pouteria campechiana*	3	0
Carambola	*Averrhoa carambola*	40	110
Guanabana	*Annona muricata*	10	0
Guava	*Psidium guajava*	700	14
Jackfruit	*Artocarpus heterophyllus*	12	4
Jujube	*Ziziphus jujube*	10	2
Longan	*Dimocarpus longan*	1,100	167
Lychee	*Litchi chinensis*	400	208
Mamey Sapote	*Pouteria sapota*	600	0
Mango	*Mangifera indica*	800	551
Miracle Fruit	*Synsepalum dulcificum*	20	0
Papaya	*Carica papaya*	300	56
Passion Fruit	*Passiflora edulis*	60	12
Pitaya	*Hylocereus undatus* and hybrids	600	121
Sapodilla	*Manilkara zapota*	200	55
Soursop	*Annona muricata*	Limited	0
Spondias	*Spondias* species	4	0
Sugar Apple	*Annona squamosa*	25	6
Wax Jambu	*Syzygium samarangense*	2	0

Information compiled in 2018

https://sfyl.ifas.ufl.edu/media/sfylifasufledu/miami-dade/documents/tropical-fruit/Tropical-Fruit-Acreage.pdf

Production data

- Acreage changes over time.
- Growers' and consumers' demands evolve.

Table 3. Land planted to minor tropical fruits in Dade County, Florida, 1982.

Fruit crop	Hectares[z]
Banana and plantain (*Musa* hybrids)	142
Papaya (*Carica papaya* L.)	142
Mamey sapote (*Calocarpum sapota* [Jacq.] Merrill)	80[y]
Acerola, Barbados cherry (*Malpighia punicifolia* L.)	12
Annonas (*A. squamosa* L., *A. squamosa* x *A. cherimola* Miller)	28
Carambola (*Averrhoa carambola* L.)	16
Longan (*Euphoria longan* [Lour.] Steud.)	12
Lychee (*Litchi chinensis* Sonn.)	60[x]
Sapodilla (*Manilkara zapota* [L.] Van Royen	8

Knight et al (1984)

Fruit	1982	2018	Fold
Banana	351	510	1.5
Papaya	351	300	0.9
Mamey Sapote	198	600	3
Annonas	69	25	0.4
Carambola	40	40	1
Longan	30	1100	37.7
Lychee	148	400	2.7
Sapodilla	20	200	10

Target traits

Avocado

- West Indian, Guatemalan, Mexican types.
- Hermaphroditic flowers: first female, second male.
- A: first AM, second PM; B: first PM, second AM.
- The only breeding program is in California?
- Bergh (1976) gives a comprehensive list of traits.
- Target: fruit quality, handling, yield, stress, etc.

Longan

- Propagate by air layering.
- Kohala is the predominant cultivar.
- Erratic bearing habit.
- Poor adaptation in other cultivars.
- No known breeding program?
- Target: bearing habit, yield, quality, etc.

Target traits

Pitaya/dragon fruit

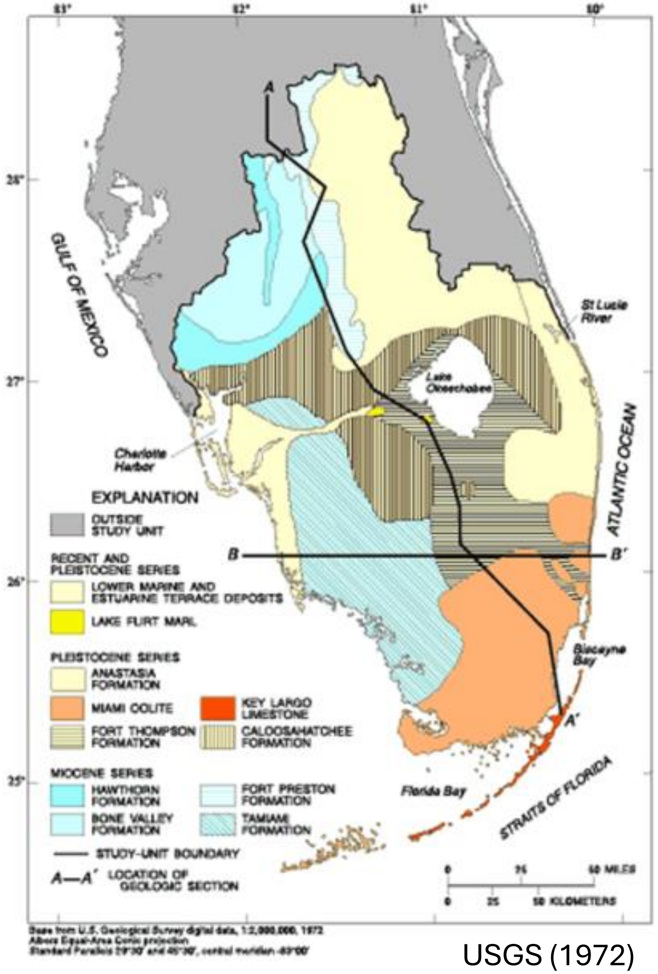
- Cultivar classifications are poorly documented.
- Multi-species (*Hylocereus undatus*, *H. monacanthus*, *H. megalanthus*, etc)
- Varying ploidy and self-compatibility.
- Nocturnal flowers.
- Target: fruit quality, post-harvest, etc.

Vanilla

- Reference genome, accessions, breeding programs already exist.
- Cultivar registration: high value, unknown sources are risky to growers.
- Target: straight bean, self-pollination (rostellum), etc.

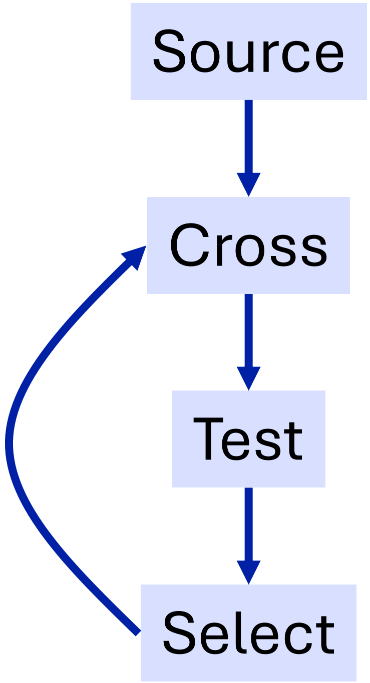
Target environment

- Oolitic limestones (rocky/marl calcareous), alkaline, > 5” (IFAS).
- Nutrient/water management.
- Works for most crops?
- Ideal temperature.
- Close to sea level.
- Tropical storms.
- Insect pest outbreak.



USGS (1972)

Breeding strategy



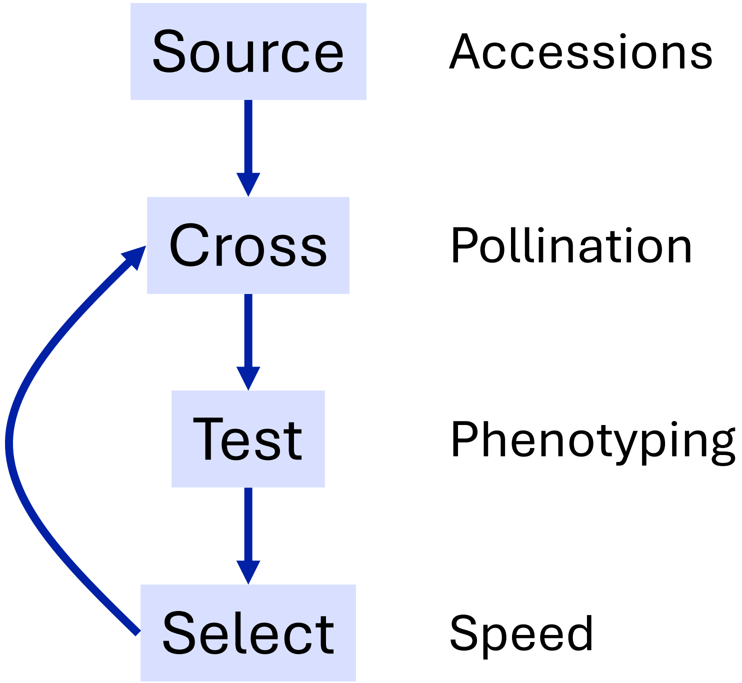
Accessions

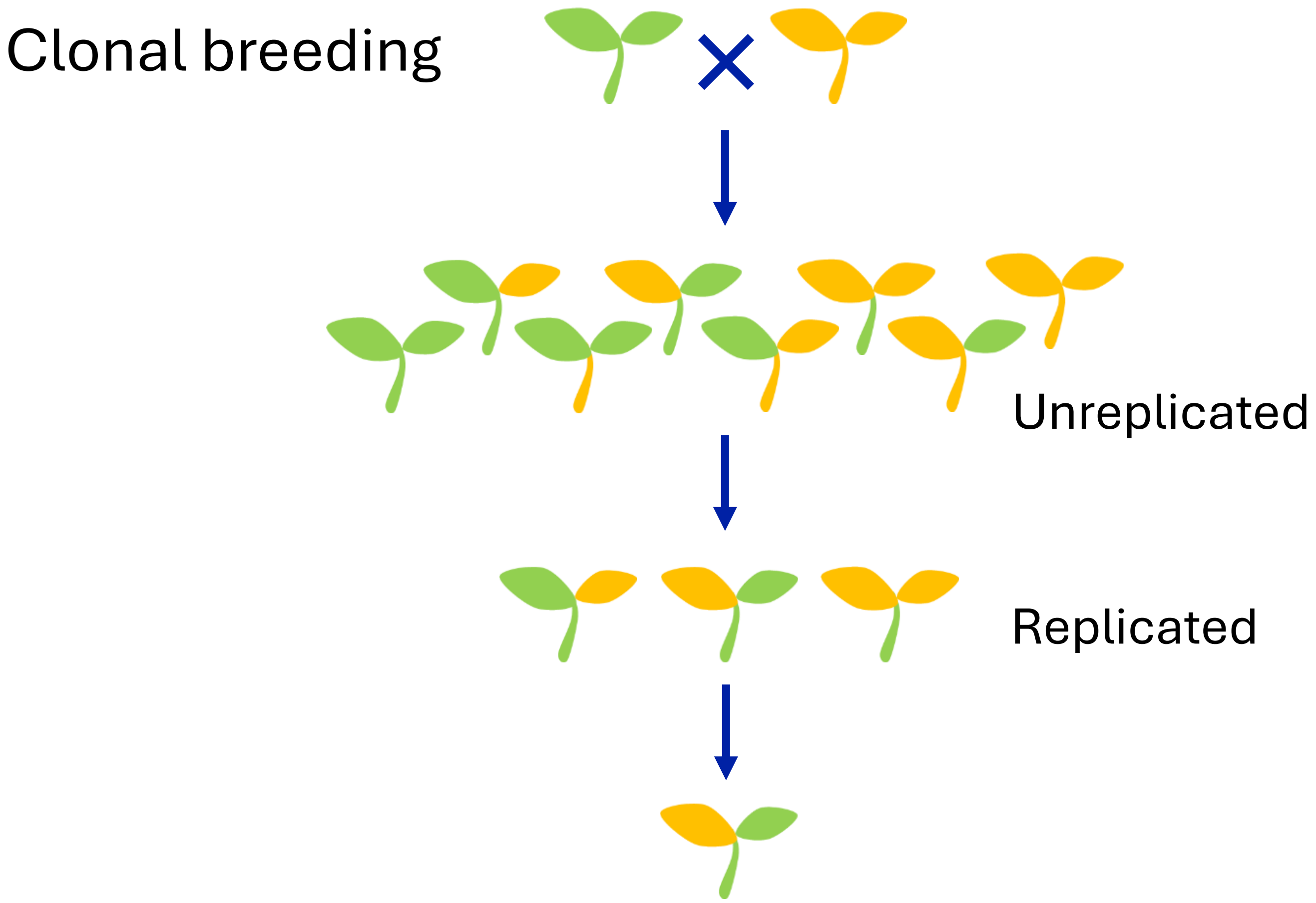
Pollination

Phenotyping

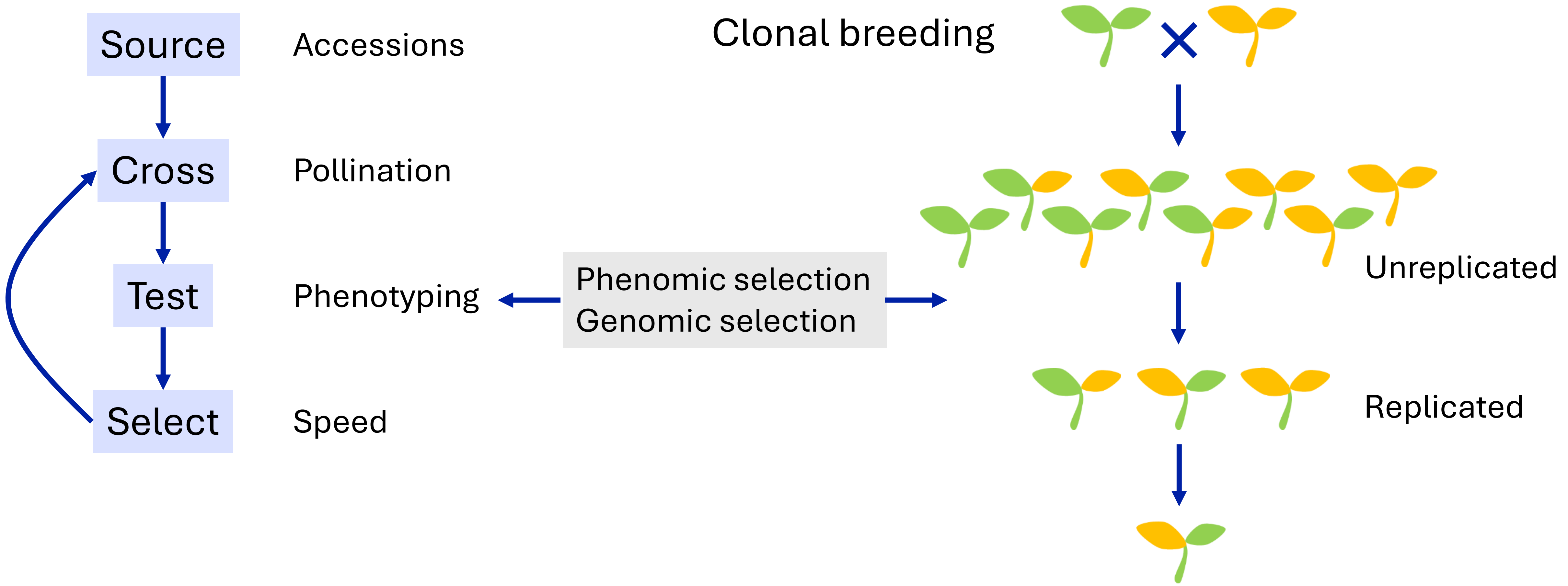
Speed

Breeding strategy





Breeding strategy



Extension vision

- Generate new knowledge.
- Give back to the local community.

Knowledge in tropical fruit crops

Diversity in:

- Genetics
- Phenotypic traits
- Nutritional qualities
- Medicinal properties
- Cultural/ethnobotanical uses

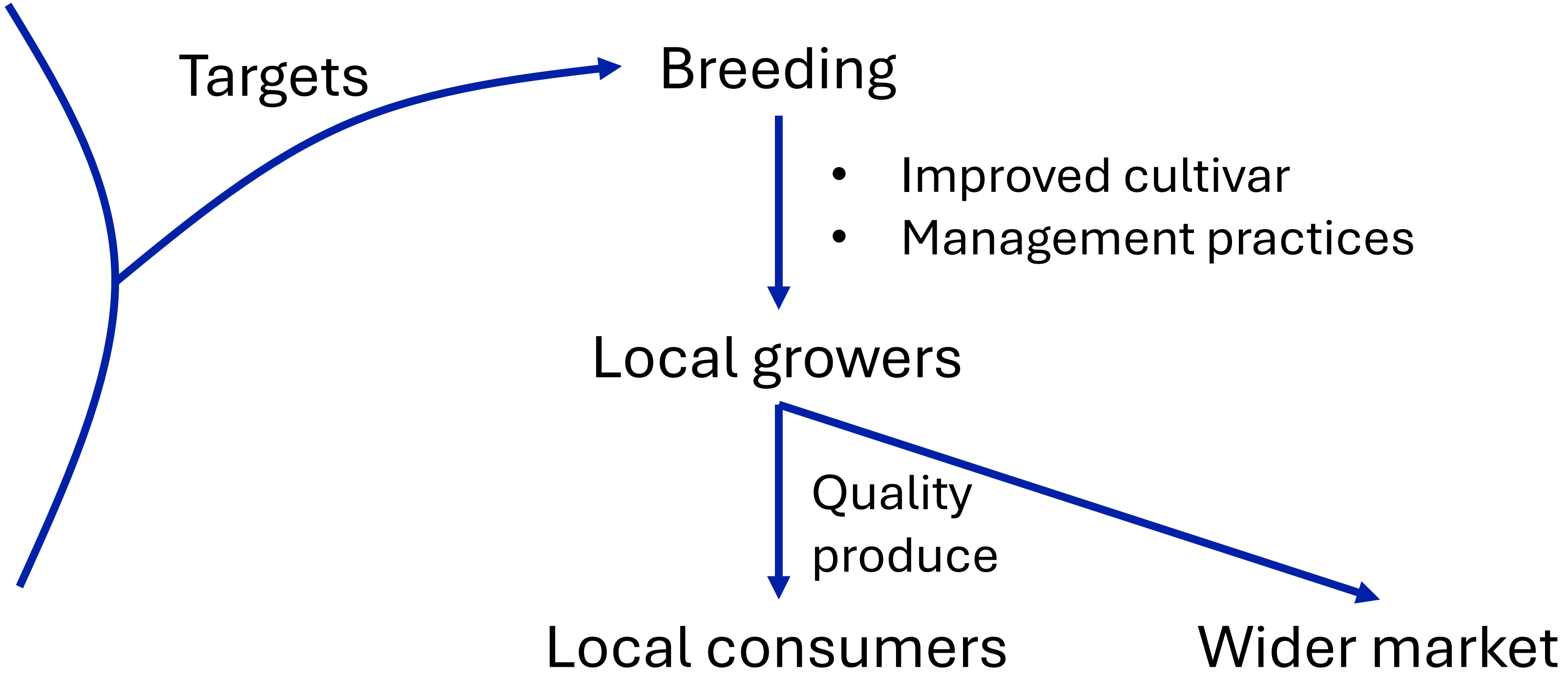
Redland market village

Tropical fruit and spice park

Knowledge in tropical fruit crops

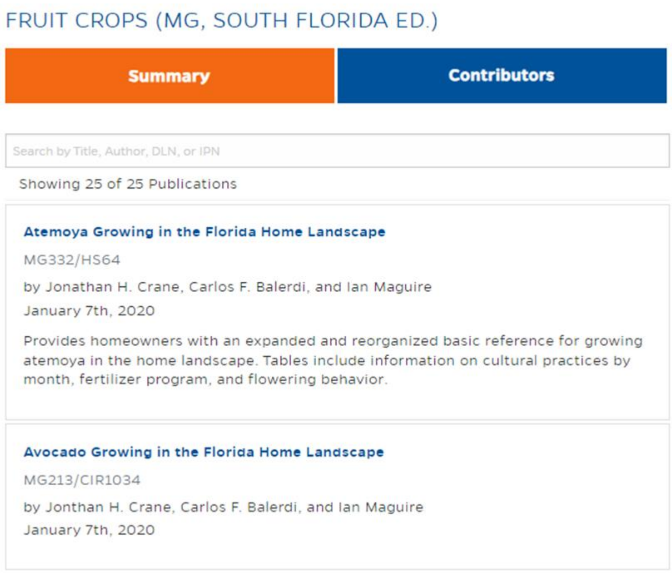
Diversity in:

- Genetics
- Phenotypic traits
- Nutritional qualities
- Medicinal properties
- Cultural uses



Plans

1. Contribute to extension publications, e.g. Ask IFAS, eXtension.org, etc.
2. Provide trainings to extension agents.
3. Apply for extramural funding, e.g. federal (NIFA), local commodity group.
4. Participate/organize extension outreach events, e.g. workshops, seminars.
5. Contribute to training programs for local growers.
6. Provide technology transfer opportunities.
7. Design breeding programs based on growers' inputs, e.g. participatory plant breeding.
8. Describe our research projects in group website and social media.



https://edis.ifas.ufl.edu/collections/mg_s_fruit_crops

Teaching vision

- Engage in IFAS land-grant mission: Research, Teaching, Extension.
- Impart learning skills to students.
- Support mentees toward research independence and excellence.

Teaching experience

2013: Teaching assistant for General Genetics, University of Wisconsin-Madison.

2021/2024: Guest lecturer for Int'l Master in Plant Genetics, Genomics and Breeding, CIHEAM Zaragoza.

2022: Guest lecturer for Genetic Improvement of Crops, University of Edinburgh.

Now: Developing module on Horticulture Biotechnology I (3rd year BSc in Horticulture).

Now: Developing module on Plant Biotechnology (MSc in Applied Plant Science).

Methods: combinations of lecture, discussion and practical (in-person/online).

Teaching approaches

Impart learning skills to students.

- *Adapt* teaching style and course contents to overall/individual needs.
- *Analogize* teaching materials using clear examples.
- *Assess* learning progress, students' needs and interests.

Cultivate a comfortable and enjoyable learning environment for every student.

Mentoring experience

1. Fine-mapping of *etb1.2*, a QTL regulating ear internode length in maize and teosinte, 2013; Jordan M.
2. Mapping prolificacy QTL in maize and teosinte, 2015-2016; Lexi C.
3. QTL mapping of domestication traits in the teosinte nested association mapping population, 2015-2018;

   Aria P, Bailey S, Brandon K, Craig D, Isaac B, Jack S, Joe P, Kyle K, Laura B, Lora D, Michael N, Sam L.
4. Genetics of sexual determination in maize/teosinte terminal lateral inflorescence, 2016; Amanda M.
5. Perennial ryegrass under speed vernalization and speed breeding conditions, 2023-2024; Leontien H.
6. Rapid domestication of purslane in a vertical farm environment, 2023-2027; Emma I.

JOURNAL ARTICLE

Mapping Prolificacy QTL in Maize and Teosinte FREE

Liyan Yang, Chin Jian Yang, Qi Cheng, Wei Xue, John F. Doebley   Author Notes

Journal of Heredity, Volume 107, Issue 7, 2016, Pages 674–678,
https://doi.org/10.1093/jhered/esw064
Published: 22 September 2016   **Article history** ▾

The genetic architecture of the maize progenitor, teosinte, and how it was altered during maize domestication

Qiuyue Chen, Luis Fernando Samayoa, Chin Jian Yang, Peter J. Bradbury, Bode A. Olukolu, Michael A. Neumeyer, Maria Cinta Romay, Qi Sun, Anne Lorant, Edward S. Buckler, Jeffrey Ross-Ibarra, James B. Holland, John F. Doebley

Version 2   Published: May 14, 2020 • https://doi.org/10.1371/journal.pgen.1008791

RESEARCH ARTICLE | BIOLOGICAL SCIENCES |

The genetic architecture of teosinte catalyzed and constrained maize domestication

Chin Jian Yang, Luis Fernando Samayoa, Peter J. Bradbury, Bode A. Olukolu, Wei Xue, Alessandra M. York, Michael R. Tuholski, Weidong Wang, Lora L. Daskalska, Michael A. Neumeyer, Jose de Jesus Sanchez-Gonzalez, Maria Cinta Romay, Jeffrey C. Glaubitz, Qi Sun, Edward S. Buckler, James B. Holland, and John F. Doebley   -13   Authors Info & Affiliations

Contributed by John F. Doebley, January 28, 2019 (sent for review December 14, 2018; reviewed by Loren H. Rieseberg and Bruce Walsh)

March 6, 2019 | 116 (12) 5643-5652 | https://doi.org/10.1073/pnas.1820997116

JOURNAL ARTICLE

TeoNAM: A Nested Association Mapping Population for Domestication and Agronomic Trait Analysis in Maize FREE

Qiuyue Chen, Chin Jian Yang, Alessandra M York, Wei Xue, Lora L Daskalska, Craig A DeValk, Kyle W Krueger, Samuel B Lawton, Bailey G Spiegelberg, Jack M Schnell, Michael A Neumeyer, Joseph S Perry, Aria C Peterson, Brandon Kim, Laura Bergstrom, Liyan Yang, Isaac C Barber, Feng Tian, John F Doebley
Author Notes

Genetics, Volume 213, Issue 3, 1 November 2019, Pages 1065–1078,
https://doi.org/10.1534/genetics.119.302594
Published: 01 November 2019   **Article history** ▾

Chapter 2

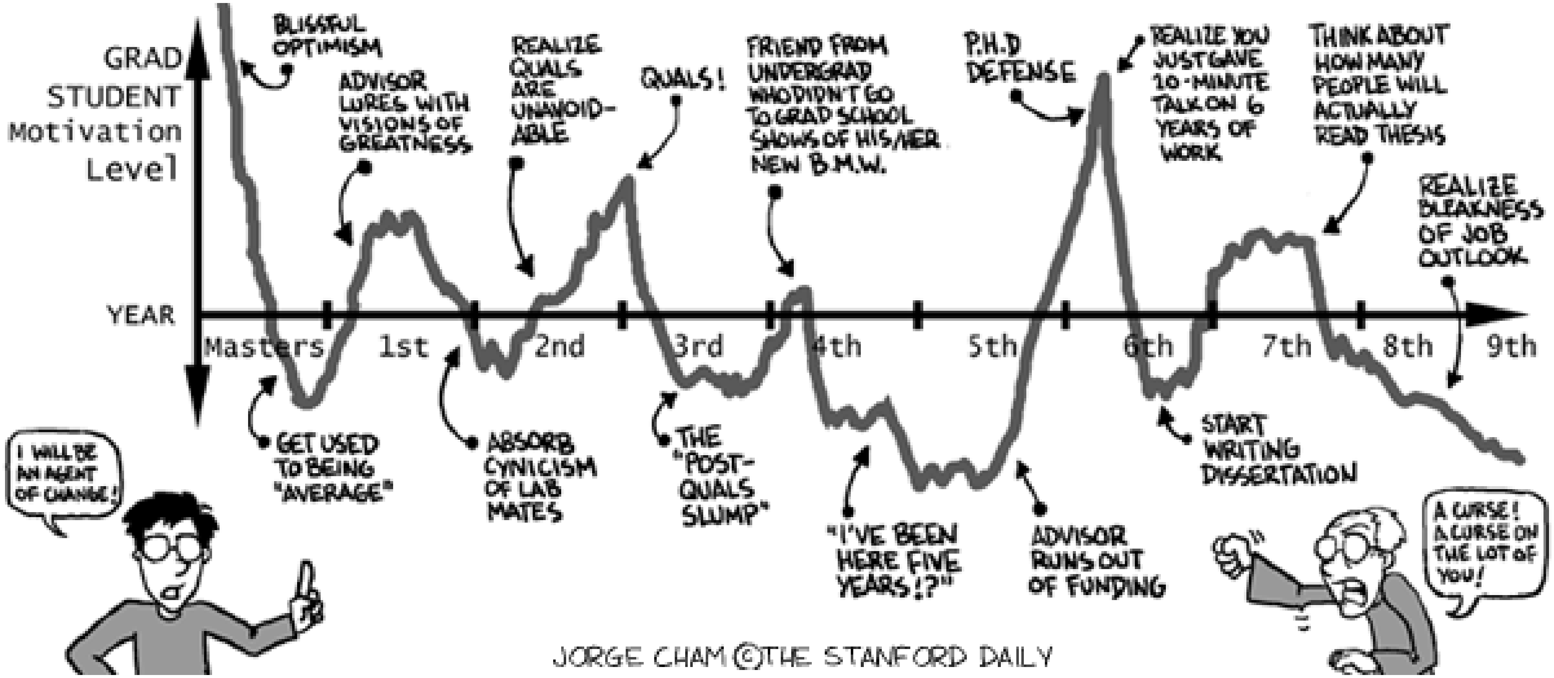
Genetic Regulation of Male-to-Female Conversion of the Terminal Lateral Inflorescence and Related Traits in Maize during Domestication

Authors: Chin Jian Yang; Amanda Alves de Melo; Joseph S. Perry; Kyle W. Krueger; Liyan Yang; John F. Doebley

Mentoring approaches

Support mentees toward research independence and excellence.

1. Understand their research interest.
2. Provide sufficient background and training.
3. Be available.
4. Be supportive.



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Summary

- Wrap-up of today’s talk.

Summary

Experience

Plant breeding and genetics

- Domestication
- Genomic selection
- Breeding program

Vision

Research: QG, simulation, state-of-the-art

Breeding: demand-driven, continuity, innovation

Extension: knowledge exchange

Teaching: learning skills, independence

Summary

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Plant breeding and genetics

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- Genomic selection
- Breeding program

Vision

Research: QG, simulation, state-of-the-art

Breeding: demand-driven, continuity, innovation

Extension: knowledge exchange

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Activities

- Research directions
- Breeding work
- Securing funding
- Developing collaboration
- Results dissemination
- Stakeholder engagement
- Training

Acknowledgement

Many thanks to the Search Committee, Tropical Research and Education Center, Department of Horticultural Sciences and UFL for the opportunity to present the talk!

<u>Wisconsin + Others</u>

John Doebley
Ali York
Qiuyue Chen
Wei Xue
Weidong Wang
Mike Tuholski
Natalia de Leon
Claudia Calderón
Jim Holland
L Fernando Samayoa
Ed Buckler
M Cinta Romay
Peter Bradbury
Many more…

<u>SRUC + Collaborators</u>

Ian Mackay
Wayne Powell
Rajiv Sharma
David Marshall
Gregor Gorjanc
Sarah Hearne
Rodney Edmondson
Hans-Peter Piepho
Joanne Russell
Like Ramsay
Bill Thomas
Funmi Ladejobi
Richard Mott

National Science Foundation
SSCR Scottish Society for Crop Research
IAEA International Atomic Energy Agency
UK Crop Diversity Bioinformatics HPC Resource
Field Spectroscopy Facility Natural Environment Research Council

https://cjyang-work.github.io/

XXX

@hataraku_cj

cjyang90

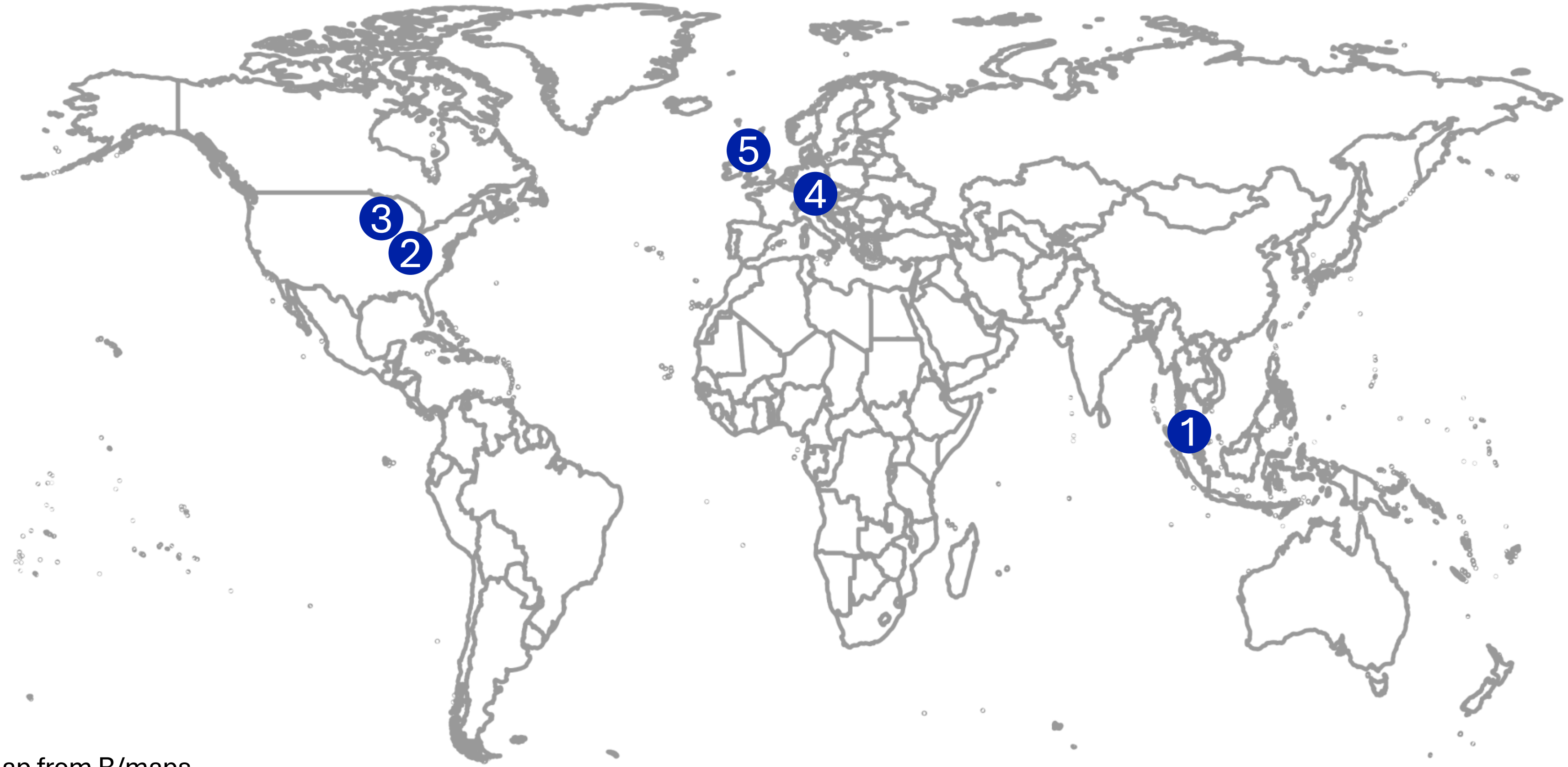
From theory to practice: applying quantitative genetics and simulation in tropical fruit crop research and breeding

CJ Yang

Gainesville, FL

Nov 14, 2023

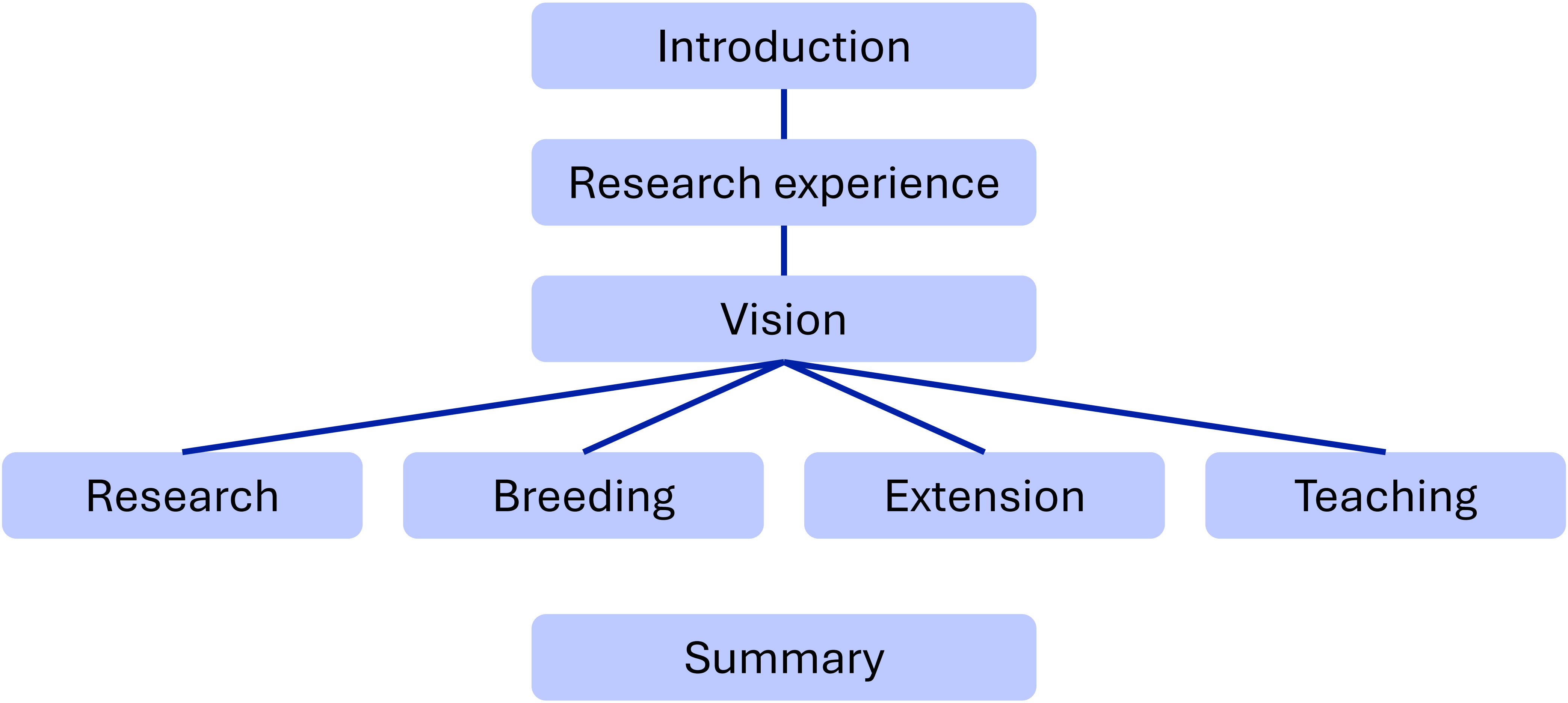
About me



Map from R/maps

1. Malaysia
2. Indiana (BSc Biotech, Maths)
3. Wisconsin (PhD Genetics)
4. Freising, DE (Postdoc)
5. Edinburgh, UK (Postdoc)

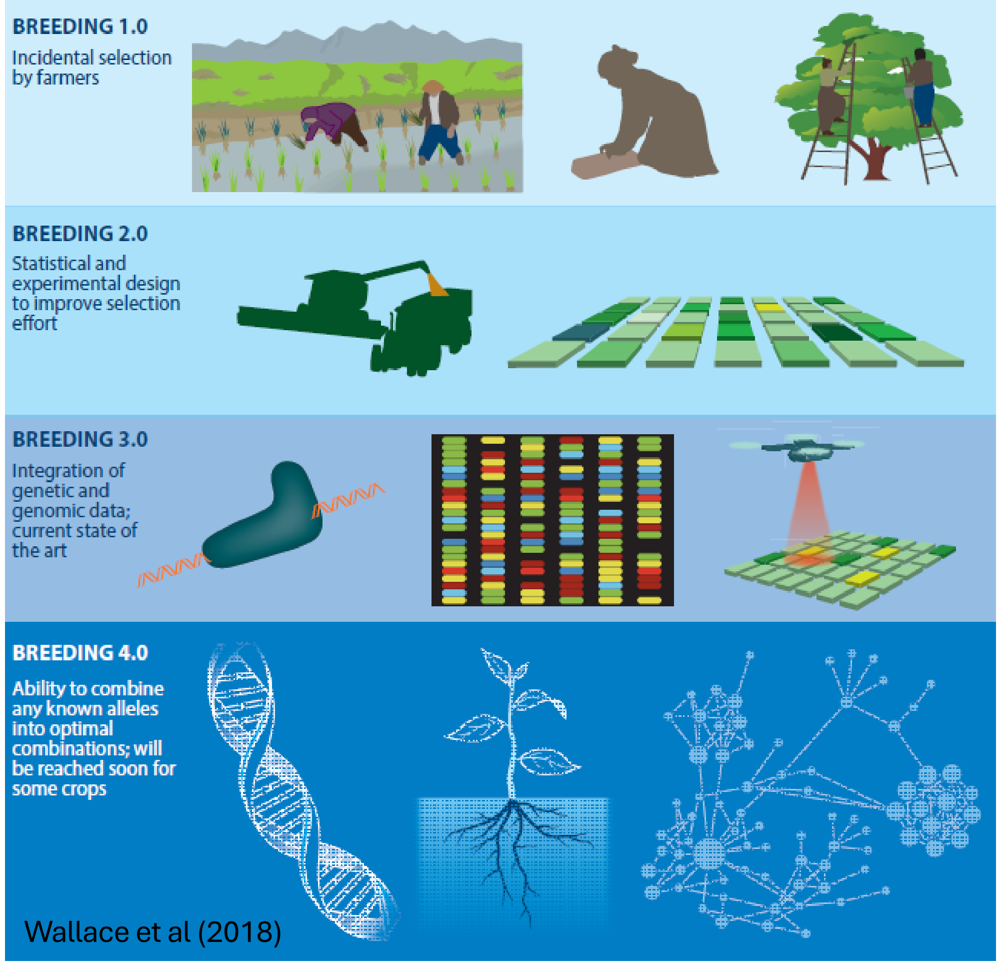
Talk outline



Introduction

Plant breeding and genetic gain

Plant Breeding



- Domestication
- Improvement

- Experimental design

- Marker assisted selection (MAS)
- Genomic/Phenomic selection (GS/PS)

- Biology-Breeding
- Functional variants
- Gene editing (GE)
- Machine learning (ML/AI)

Genetic Gain

Breeder's equation

(Lush 1937)

$$R = h^2 S$$

$$R = \frac{\sigma_g^2}{\sigma_p^2} \sigma_p i$$

$$R = \frac{\sigma_g}{\sigma_p} \sigma_g i$$

$$R = h \sigma_g i$$

Rate of genetic gain

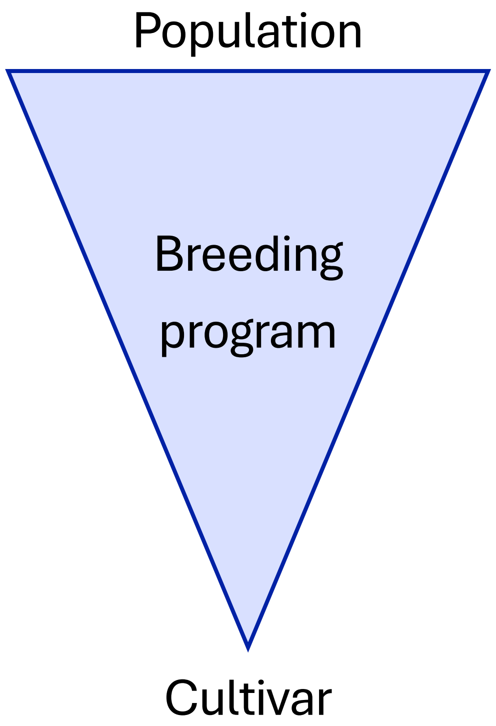
$$\Delta R = \frac{h \sigma_g i}{t}$$

$$\Delta R = \frac{sel.accuracy \times genetic\ variation \times sel.intensity}{time}$$

Framework for quantitative genetics

Improving ΔR

$$\Delta R = \frac{sel.accuracy \times genetic\ variation \times sel.intensity}{time}$$



- Multiparental population, mutation, pre-breeding.
- MAS, GS, GE, phenomics.
- Larger/efficient trials.
- Rapid cycling, speed breeding (SB/RGA).

Research experience

Plant breeding: a journey through time

Domestication

This earliest form of plant breeding is known as domestication, where plants were selected to be more productive, easier to harvest, or more aesthetically or gastronomically pleasing (Flint-Garcia 2013).

Domestication

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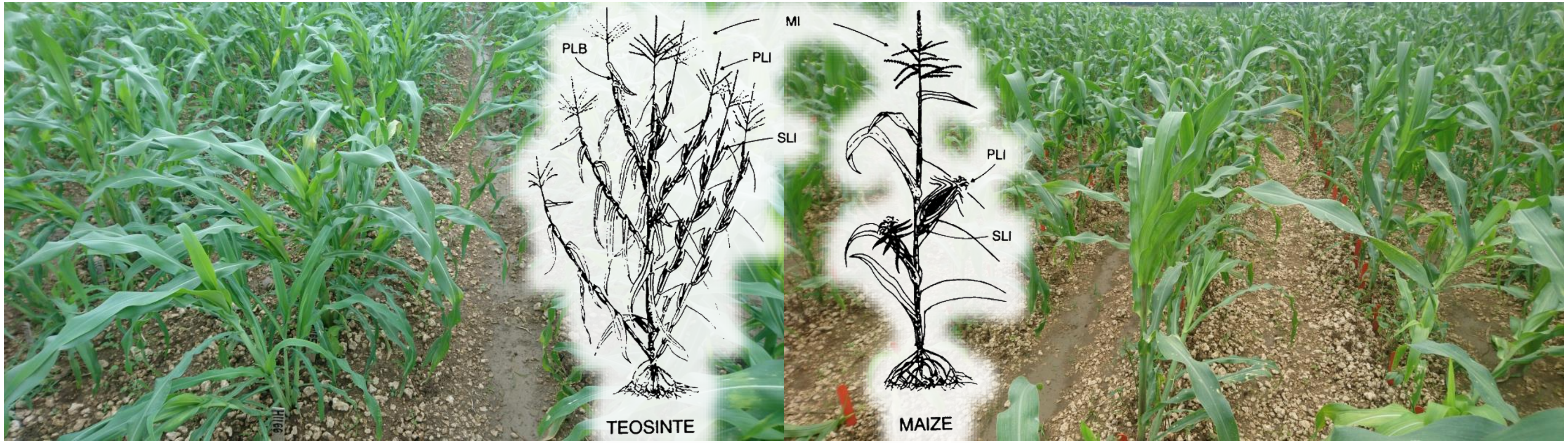
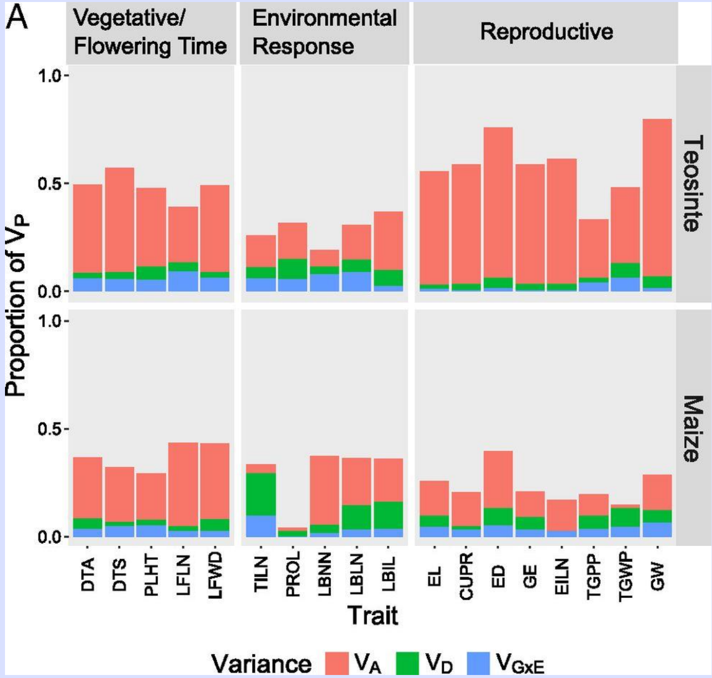


Teosinte (left) and maize (right) in Homestead, FL, 2013-2017.

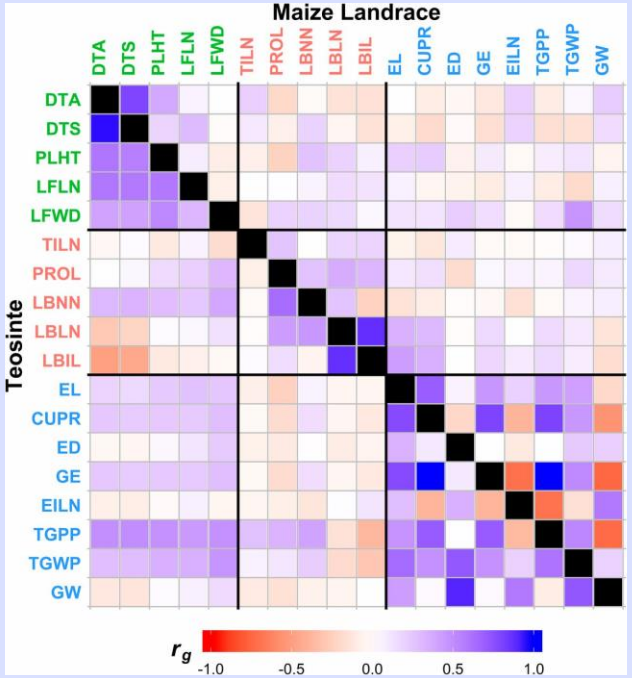
Drawings from Doebley et al (1990)

QG modelling of domestication

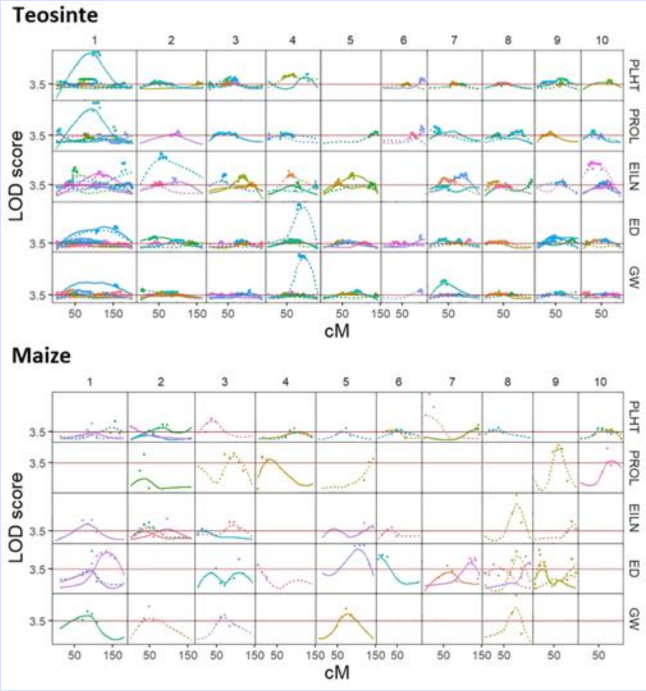
Reduction in genetic variances.



Change in genetic correlations.



Increase in inbreeding depression.
Decrease in rare deleterious alleles.

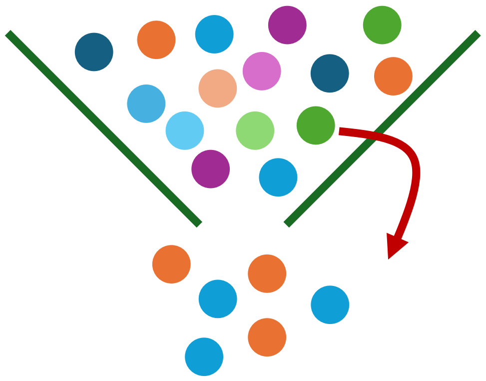


Yang et al (2019), Chen et al (2020, 2021), Samayoa et al (2021)

Shuffling genetic diversity

Domestication/Improvement

- Bottleneck
- Selection

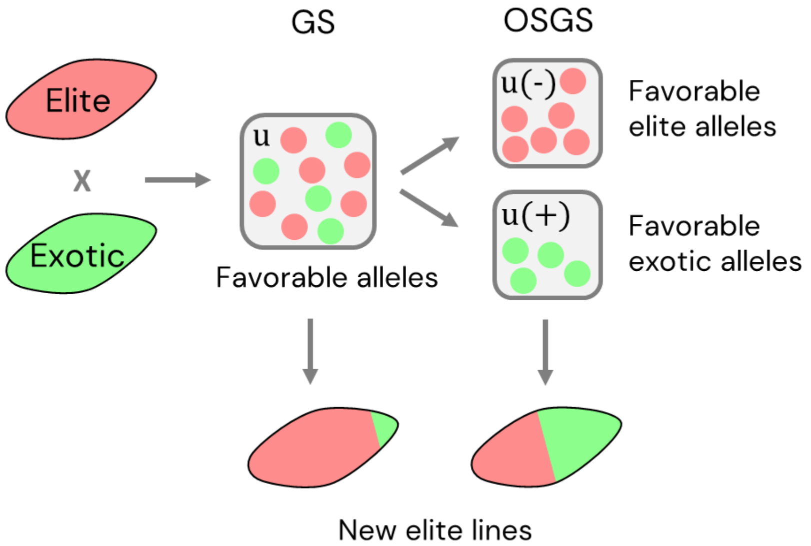


Marker assisted selection (MAS)

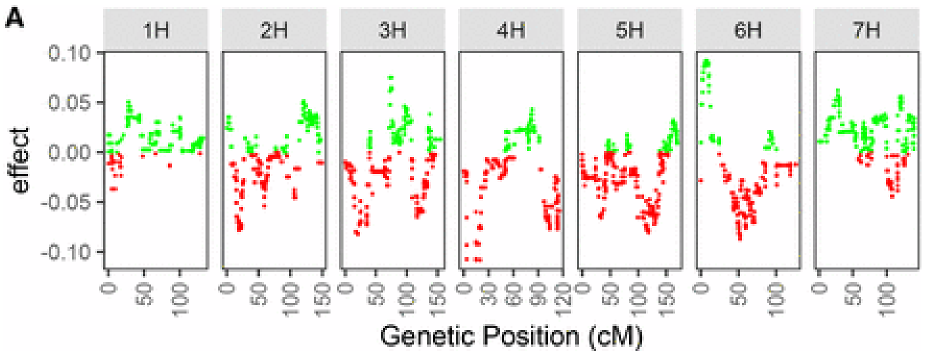
- Great for oligogenic traits.
- E.g. disease resistance.
- Inefficient for polygenic traits.

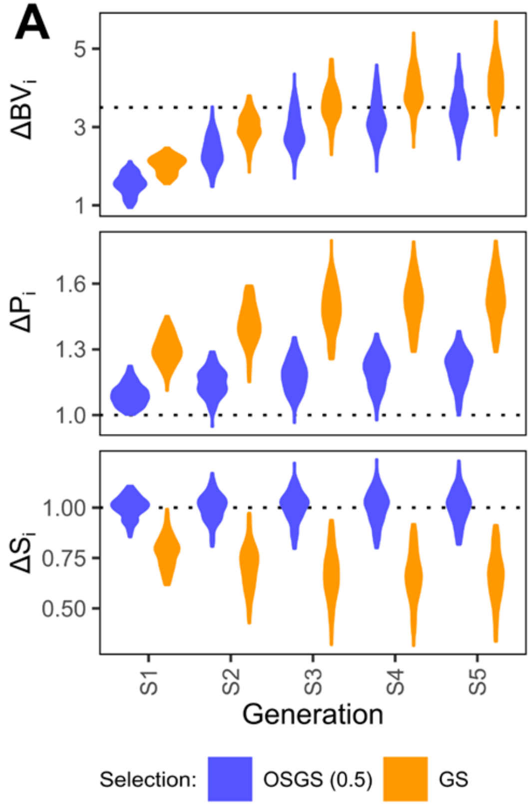
Origin specific genomic selection (OSGS)

OSGS: selection on favorable parental contribution.



Yield in a barley NAM family





Yang et al (2020)

Developing a breeding program for purslane

- Env: Vertical farm
- Trait: Omega-3 level

Table 2: Plant sources of omega-3 fatty acids (g/100 g).

Category	Fruits/vegetables	Amount (g)
	Avocados, California raw	0.1
	Broccoli	0.1
	Strawberries	0.1
	Cauliflower, raw	0.1
Low	Kale, raw	0.2
	Spinach, raw	0.1
	Peas, garden dry	0.2
	Cowpeas, dry	0.3
	Beans, navy, sprouted, cooked	0.3
	Corn, germ	0.3
	Bean, common dry	0.6
	Leeks, freeze-dried, raw	0.7
	Wheat, germ	0.7
	Spirulina, dried	0.8
Medium	Purslane	0.9
	Oat, germ	1.4
	Beachnuts	1.7
	Soybeans kernels, roasted	1.5
	Soybeans, green	3.2

Uddin et al (2014)

Identify breeding targets.

Survey variation in phenotypes, GxExM.

Engage with stakeholders.

Register varieties.

Create populations and select.

Trial in vertical farms.

Short vs long day

Fluorescent vs LED

Developing a breeding program for purslane

Royal Highland Show

Identify breeding targets.

Survey variation in phenotypes, GxExM.

Engage with stakeholders.

Register varieties.

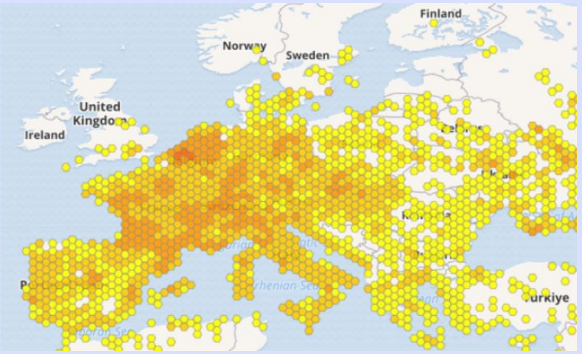
Create populations and select.

Trial in vertical farms.

Green vs golden purslane

Developing a breeding program for purslane

Sample collection



GBIF (2014-2023)

NBN Atlas

Identify breeding targets.

Survey variation in phenotypes, GxExM.

Engage with stakeholders.

Register varieties.

Create populations and select.

Trial in vertical farms.

Growth chambers

Hydroponic trials

VF – under construction

Research vision

Applying innovations from modern quantitative genetics to:

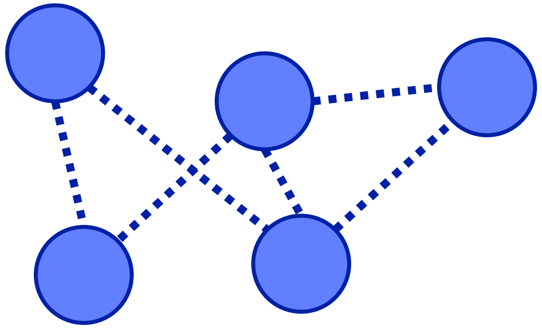
- identify ways to breed for improved tropical fruit cultivars
- understand tropical fruit genetics
- design efficient and resilient breeding programs

Area 1: Genomic selection (GS)

Genomic selection models: G-BLUP, RR-BLUP, LASSO, Bayes?, etc...

$y = Xb + g + e$ ➡ Decompose phenotype into various effects.

$g \sim N(0, K\sigma_g^2)$ ➡ Based on genotypic relationship K.



Considerations

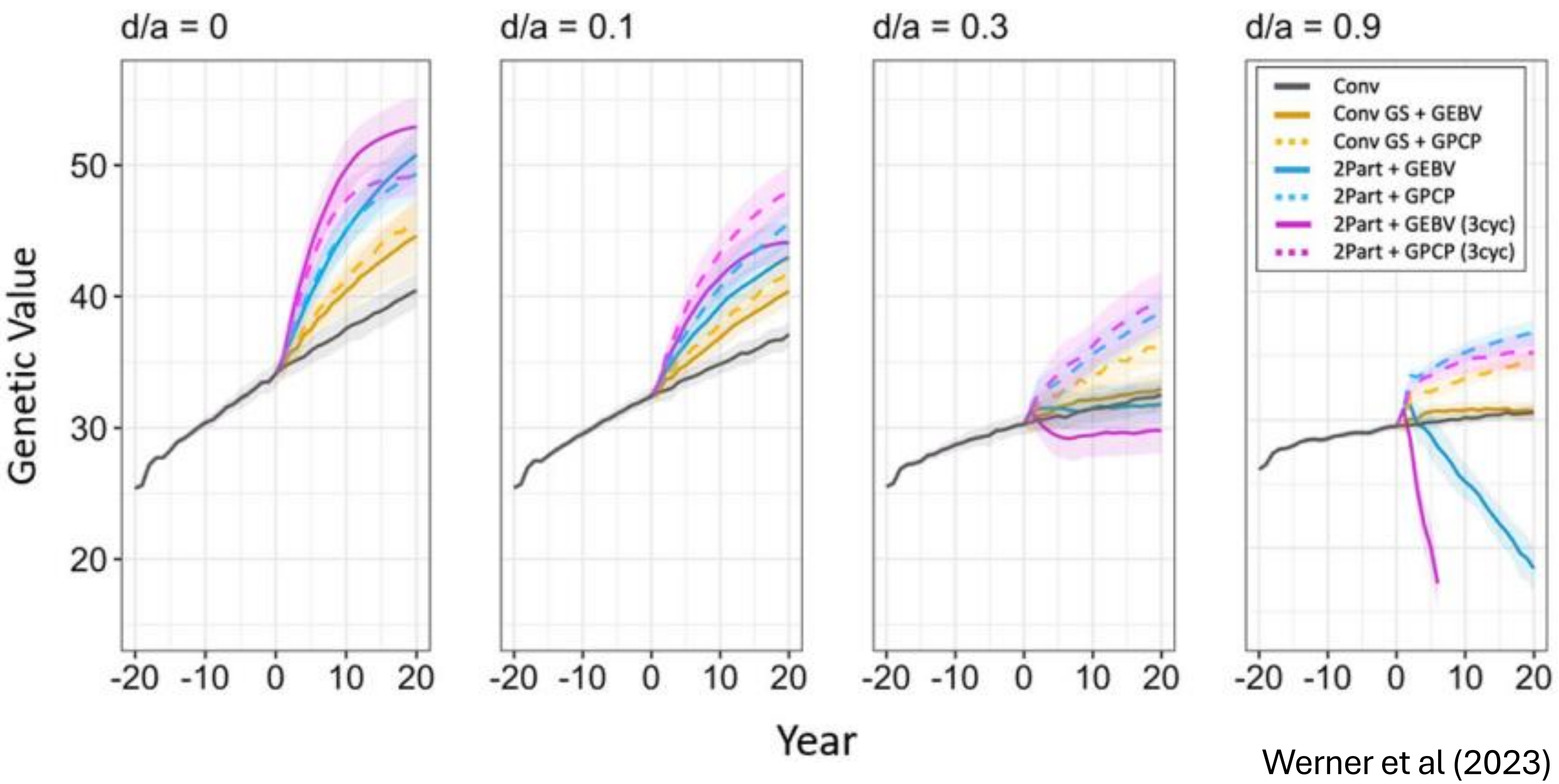
GS requires

- relationship between training and testing populations
- reliable genotyping platform
- good phenotyping quality, reasonable trials
- heritable polygenic traits
- sufficient computational power
- justifiable benefit over phenotypic selection

GS gives

- increase selection accuracy
- increase selection intensity
- reduce breeding cycle time

Clonal breeding example



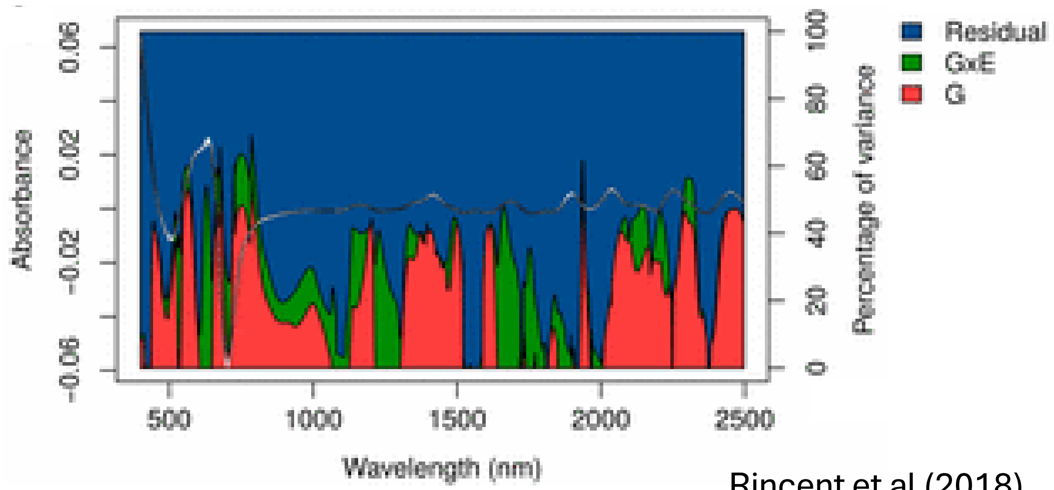
Werner et al (2023)

- Evaluate breeding strategy using simulation.
- Strawberry breeding example.
- 3 breeding programs.
- 2 parental selection methods.
- Effect of dominance on genetic gain.

Area 2: Phenomic selection (PS)

$$y = Xb + g + e \qquad g \sim N(0, K\sigma_g^2)$$

Previously, we showed the role of genotypic relationship K in the GS model.



Rincent et al (2018)

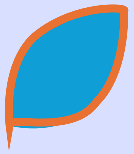
- Replace genome by phenome in calculating K.
- Phenome can be near-infrared spectra (NIRS), image data, other omics, etc.
- Part of the phenome is heritable.
- Phenome captures G x E x M.
- Phenome is cheap(?).

Current state of PS

- Results on PS is mixed.
- PS vs GS depends on population and trait.
- Post-flowering phenome (e.g. seeds) may be inefficient.

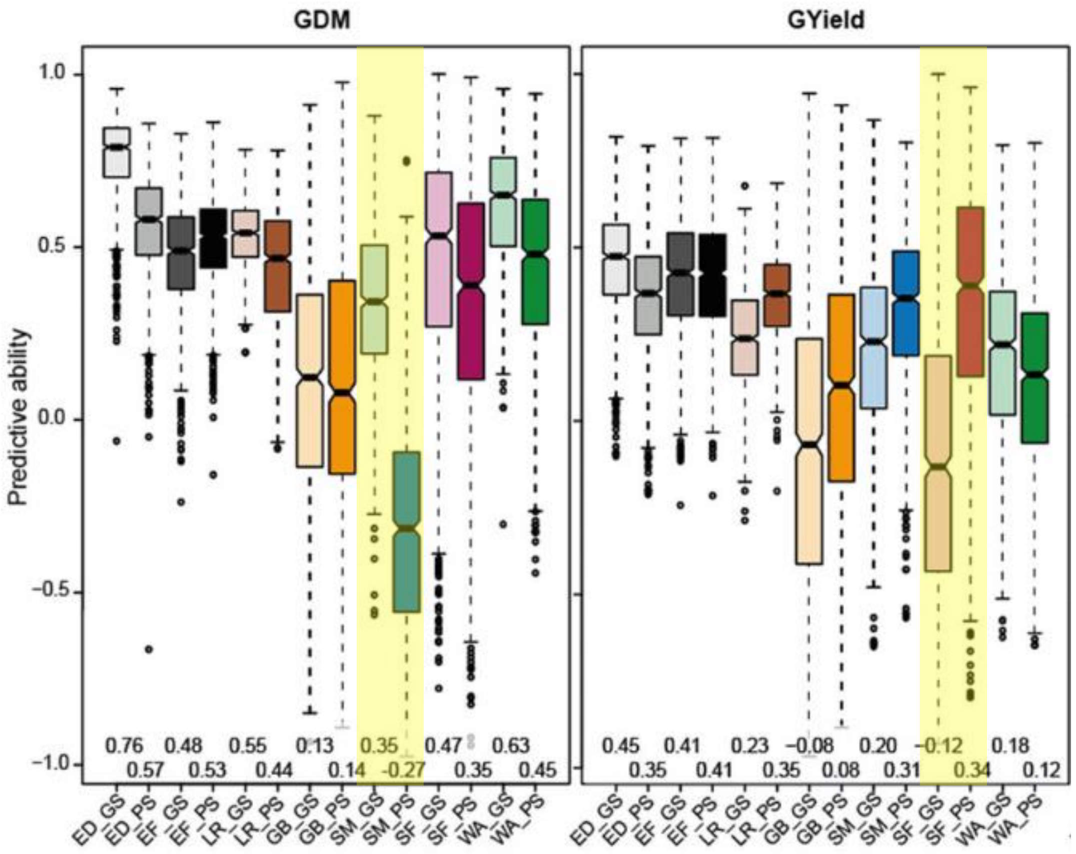
Line 1, Env 1 → Line 1, Env 2

- Biased toward information within the predictors (Dallinger et al, 2023).



Grain Protein ↓ Yield ↑

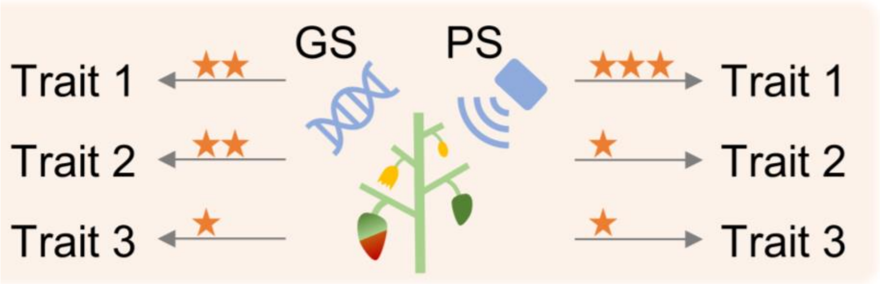
Direct vs indirect selection



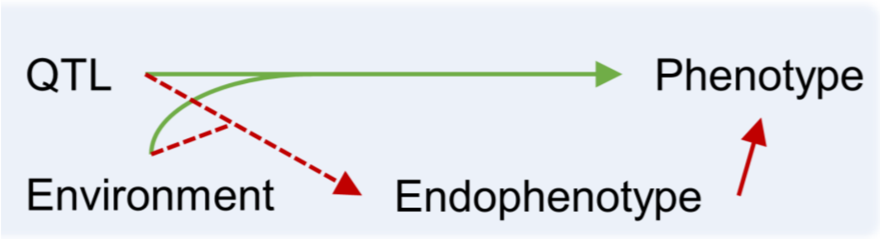
Weiss et al (2022)

Opportunities in PS

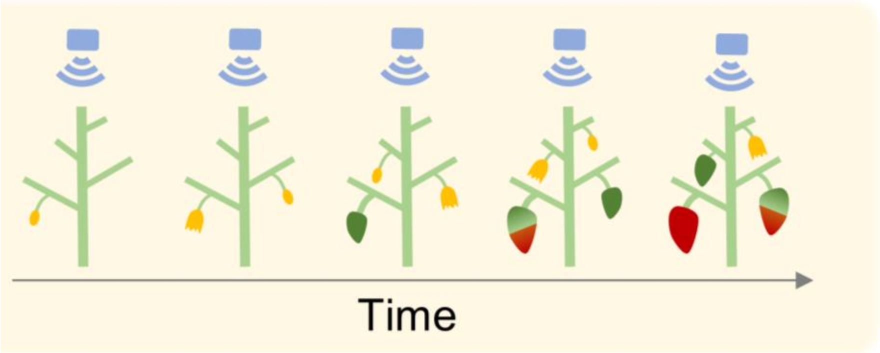
Compare GS and PS in different traits.



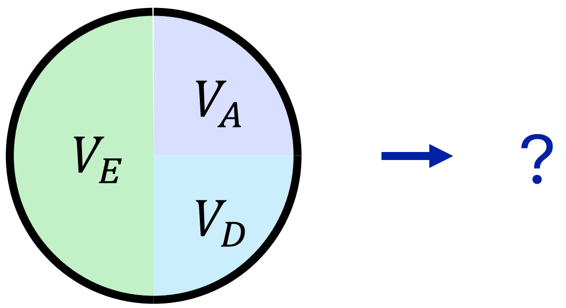
Develop methods for simulating phenome.



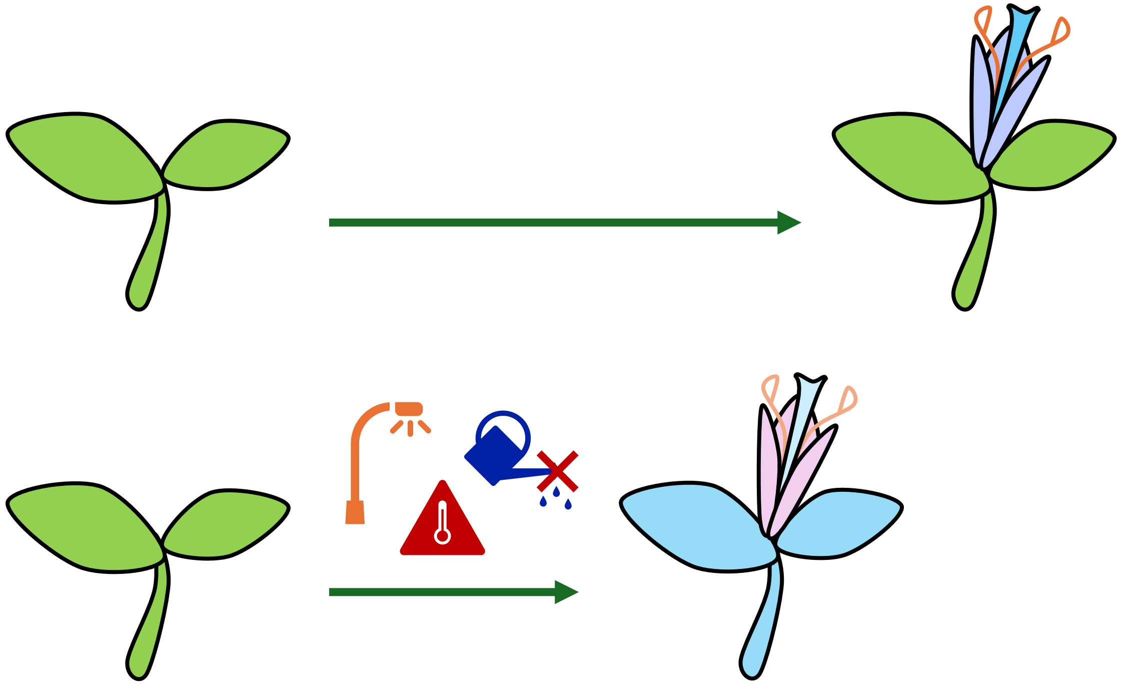
Evaluate PS across developmental time points.



Quantify "phenomic architecture" of traits.



Area 3: Speed breeding (SB)



Example in pine.

https://www.theguardian.com/environment/2022/oct/01/scotland-vertical-farming-boost-tree-stocks-hydroponics

- SB reduces the juvenile phase and breeding cycle.
- Feasible? Limited controlled environment space, short-day (photoperiod sensitive) plants.

Genetics-based SB

Standing variation

- Apply selection for early (stable) flowering and reduced photoperiod sensitivity.

Induced diversity

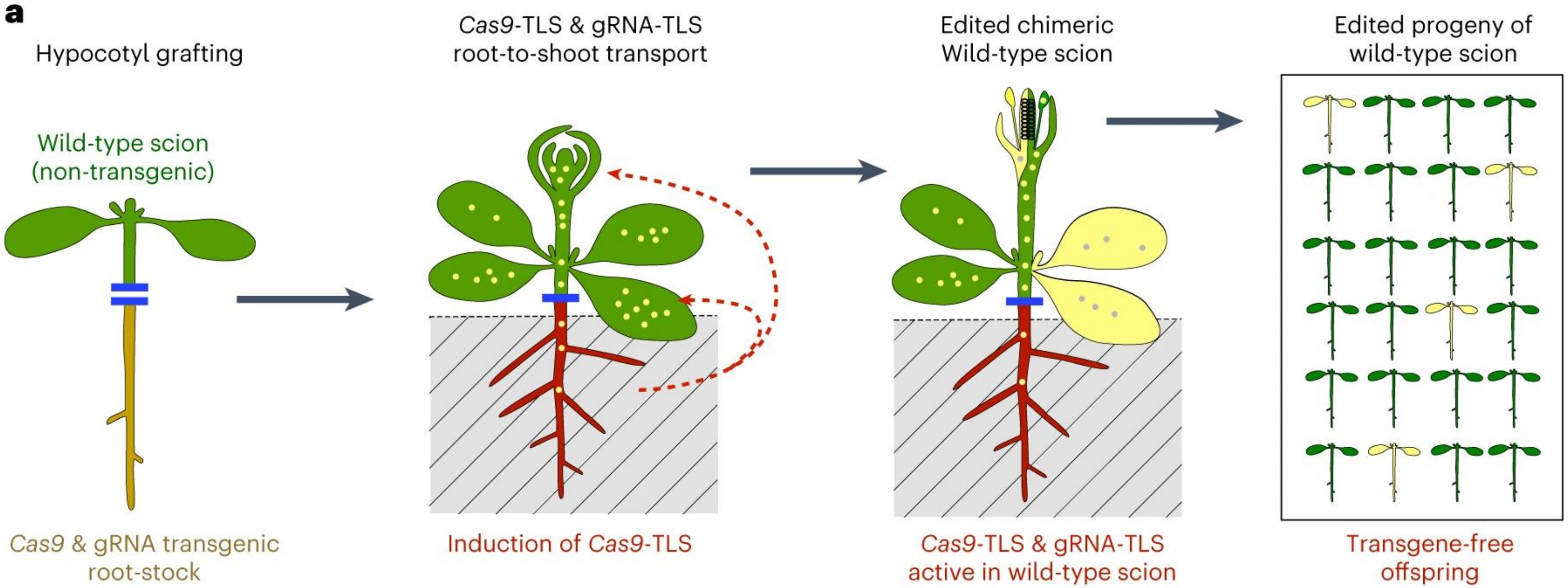
- Random: apply EMS mutagenesis, TILLING population.
- Targeted: comparative genomics and gene editing.

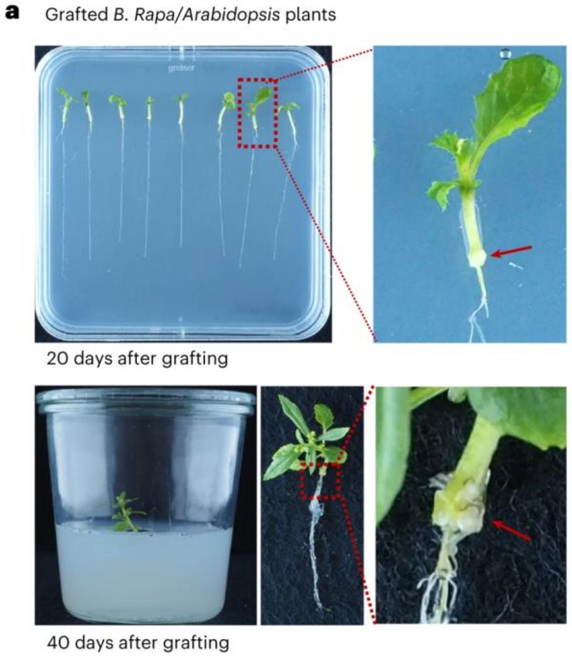
Other approach

- Graft* breeding individuals onto gene edited individuals.

Gene editing and grafting

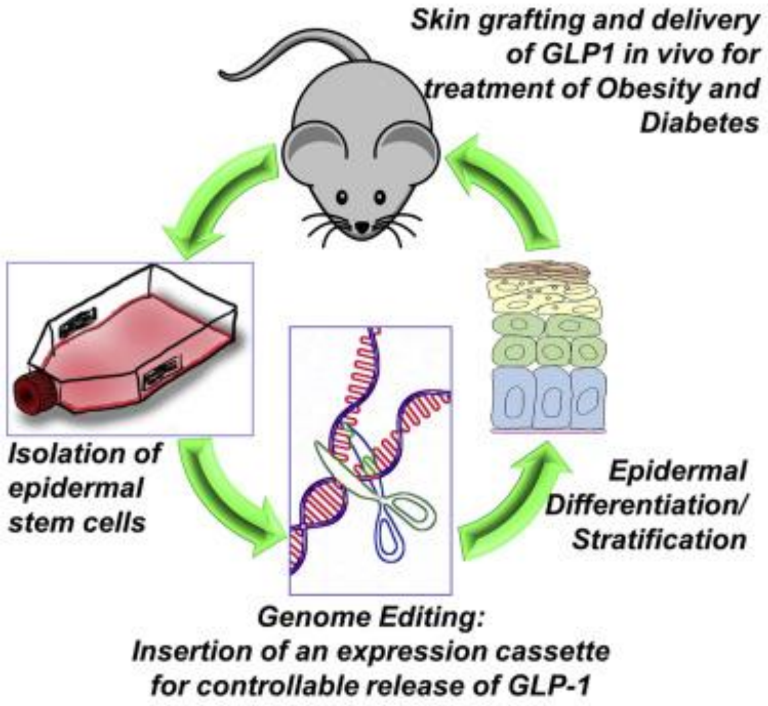
Recently demonstrated in Arabidopsis and *Brassica rapa*.





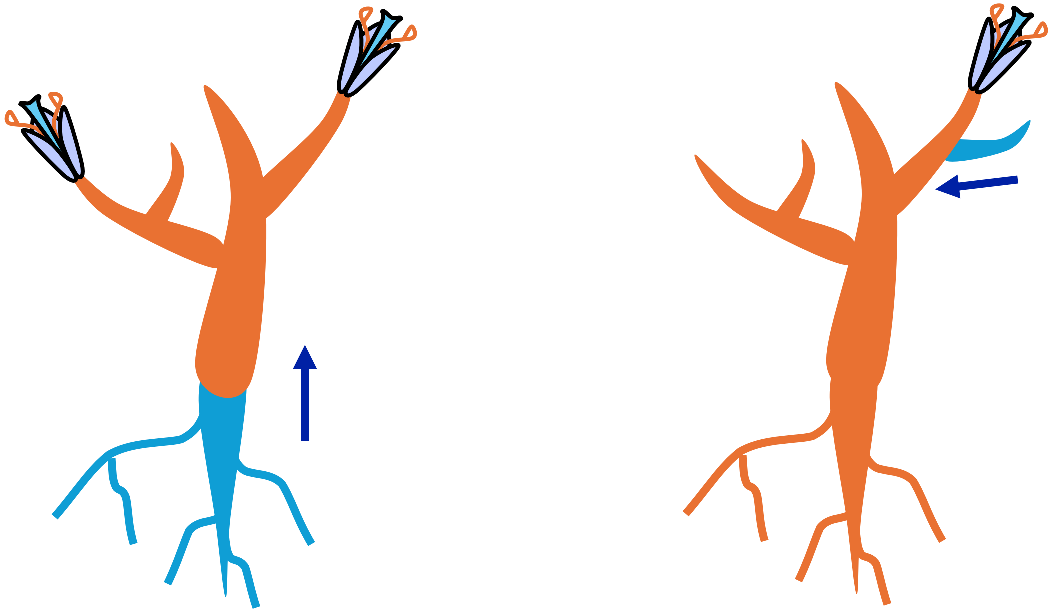
Yang L et al (2023)

Gene editing and grafting



Yue et al (2017)

- Similar experiment has been shown in mice.
- Many possibilities: not limited to gene editing rootstock.



Collaboration and funding

Interdisciplinary projects

- Quantitative Genetics
- Simulation
- Statistics
- Bioinformatics
- Phenomics
- Crop production
- Agronomy
- Plant physiology
- Molecular biology
- Gene editing
- Plant pathology
- Entomology
- Environmental Hort
- Agroecology
- Economics

TROPICAL FRUIT GROWERS of South Florida

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE
Subtropical Horticulture Research: Miami, FL

Preston B. Bird and Mary Heinlein FRUIT & SPICE PARK

FAIRCHILD TROPICAL BOTANIC GARDEN

Breeding vision

- Breed for the needs of local growers.
- Ensure continuity in pre-existing breeding programs.
- Identify opportunities for improvement (evidence-based).

Tropical fruits


Banana


Carambola


Longan


Papaya


Passion fruit


Sapodilla


Pitaya


Avocado

https://commons.wikimedia.org/wiki/File:Avacado_on_tree_(closeup).JPG


Mango

https://commons.wikimedia.org/wiki/File:Mango_%27Julie%27_Fruits.jpg


Lychee

https://commons.wikimedia.org/wiki/File:Litchi_chinensis_fruits.JPG


Guava

https://commons.wikimedia.org/wiki/File:Guava_Fruit.jpg


Mamey sapote

https://commons.wikimedia.org/wiki/File:Mamey.jpg


Sugar apple

https://commons.wikimedia.org/wiki/File:Sugar_apple_on_tree.jpg


Vanilla

https://commons.wikimedia.org/wiki/File:Vanilla_planifolia_(6998639597).jpg

Production data

UF | IFAS Extension UNIVERSITY of FLORIDA MIAMI-DADE COUNTY

Tropical Fruit Acreage in Florida

Jonathan H. Crane, UF/IFAS TREC and Jeff Wasielewski, UF/IFAS Extension Miami-Dade County

Common Name	Scientific Name	Miami-Dade County	Other Counties in FL
Atemoya	*Annona cherimola x A. squamosa*	Limited	Limited
Avocado	*Persea americana*	6,600	55
Banana	*Musa* hybrids	510	50
Caimito (star apple)	*Chyrsophyllum cainito*	10	1
Canistel (egg fruit)	*Pouteria campechiana*	3	0
Carambola	*Averrhoa carambola*	40	110
Guanabana	*Annona muricata*	10	0
Guava	*Psidium guajava*	700	14
Jackfruit	*Artocarpus heterophyllus*	12	4
Jujube	*Ziziphus jujube*	10	2
Longan	*Dimocarpus longan*	1,100	167
Lychee	*Litchi chinensis*	400	208
Mamey Sapote	*Pouteria sapota*	600	0
Mango	*Mangifera indica*	800	551
Miracle Fruit	*Synsepalum dulcificum*	20	0
Papaya	*Carica papaya*	300	56
Passion Fruit	*Passiflora edulis*	60	12
Pitaya	*Hylocereus undatus* and hybrids	600	121
Sapodilla	*Manilkara zapota*	200	55
Soursop	*Annona muricata*	Limited	0
Spondias	*Spondias* species	4	0
Sugar Apple	*Annona squamosa*	25	6
Wax Jambu	*Syzygium samarangense*	2	0

Information compiled in 2018

https://sfyl.ifas.ufl.edu/media/sfylifasufledu/miami-dade/documents/tropical-fruit/Tropical-Fruit-Acreage.pdf

Production data

- Acreage changes over time.
- Growers' and consumers' demands evolve.

Table 3. Land planted to minor tropical fruits in Dade County, Florida, 1982.

Fruit crop	Hectares[z]
Banana and plantain (*Musa* hybrids)	142
Papaya (*Carica papaya* L.)	142
Mamey sapote (*Calocarpum sapota* [Jacq.] Merrill)	80[y]
Acerola, Barbados cherry (*Malpighia punicifolia* L.)	12
Annonas (*A. squamosa* L., *A. squamosa* x *A. cherimola* Miller)	28
Carambola (*Averrhoa carambola* L.)	16
Longan (*Euphoria longan* [Lour.] Steud.)	12
Lychee (*Litchi chinensis* Sonn.)	60[x]
Sapodilla (*Manilkara zapota* [L.] Van Royen	8

Knight et al (1984)

Fruit	1982	2018	Fold
Banana	351	510	1.5
Papaya	351	300	0.9
Mamey Sapote	198	600	3
Annonas	69	25	0.4
Carambola	40	40	1
Longan	30	1100	37.7
Lychee	148	400	2.7
Sapodilla	20	200	10

Target traits

Avocado

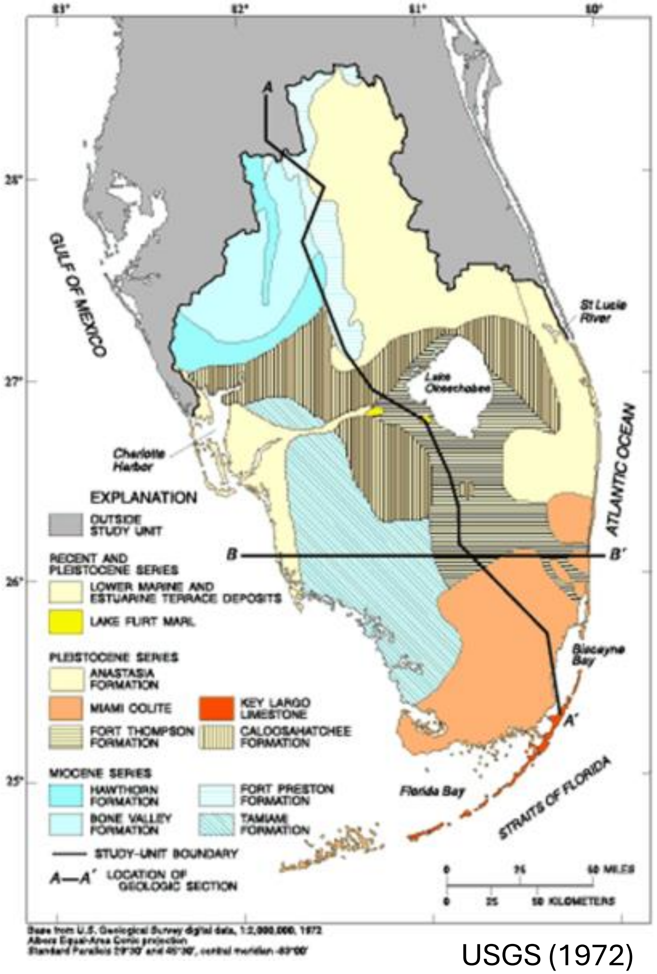
- West Indian, Guatemalan, Mexican types.
- Hermaphroditic flowers: first female, second male.
- A: first AM, second PM; B: first PM, second AM.
- The only breeding program is in California?
- Bergh (1976) gives a comprehensive list of traits.
- Target: fruit quality, handling, yield, stress, etc.

Longan

- Propagate by air layering.
- Kohala is the predominant cultivar.
- Erratic bearing habit.
- Poor adaptation in other cultivars.
- No known breeding program?
- Target: bearing habit, yield, quality, etc.

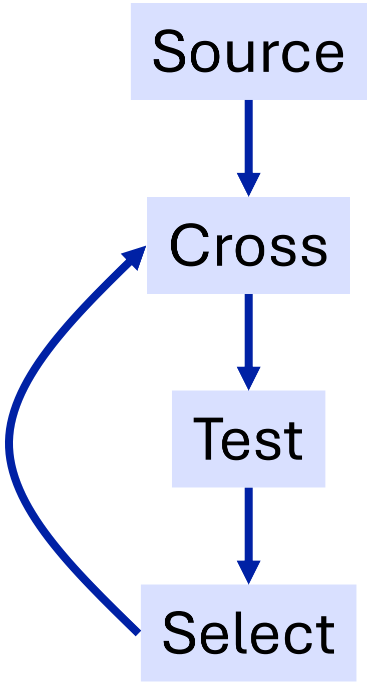
Target environment

- Oolitic limestones (rocky/marl calcareous), alkaline, > 5” (IFAS).
- Nutrient/water management.
- Works for most crops?
- Ideal temperature.
- Close to sea level.
- Tropical storms.
- Insect pest outbreak.



USGS (1972)

Breeding strategy



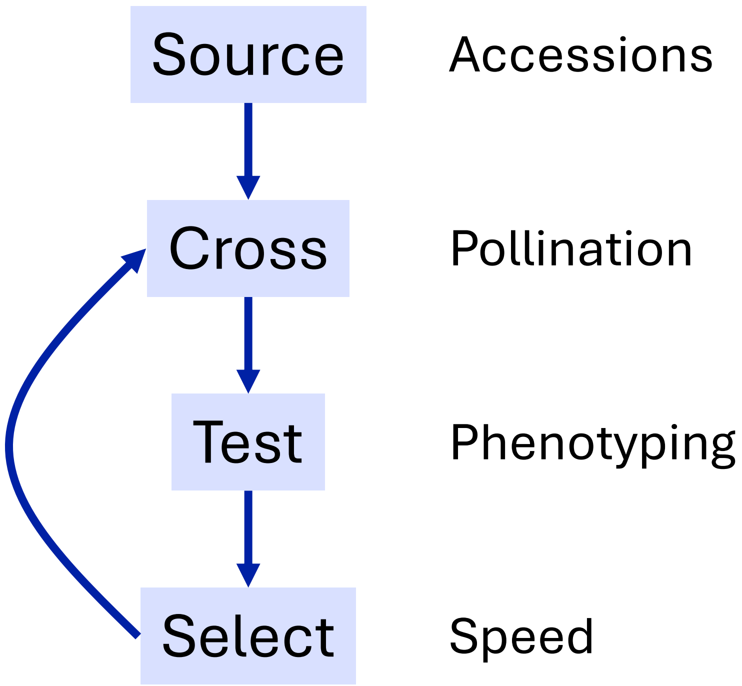
Accessions

Pollination

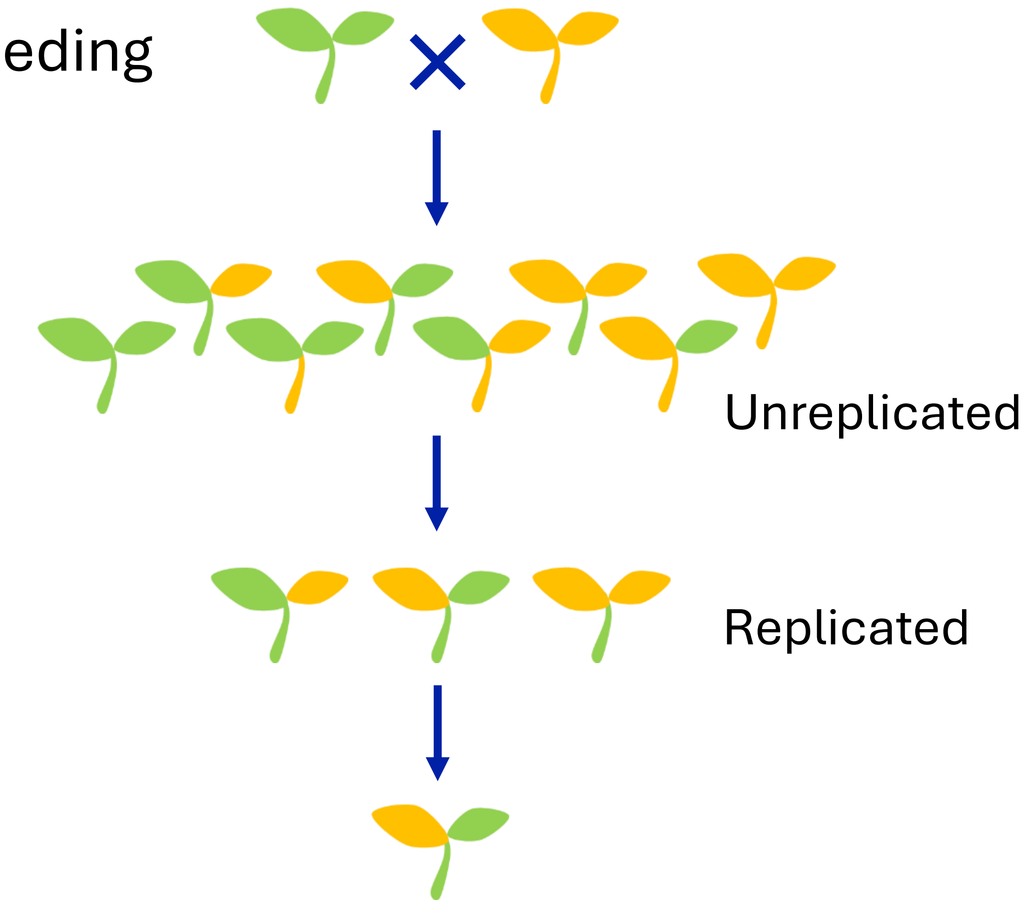
Phenotyping

Speed

Breeding strategy



Clonal breeding

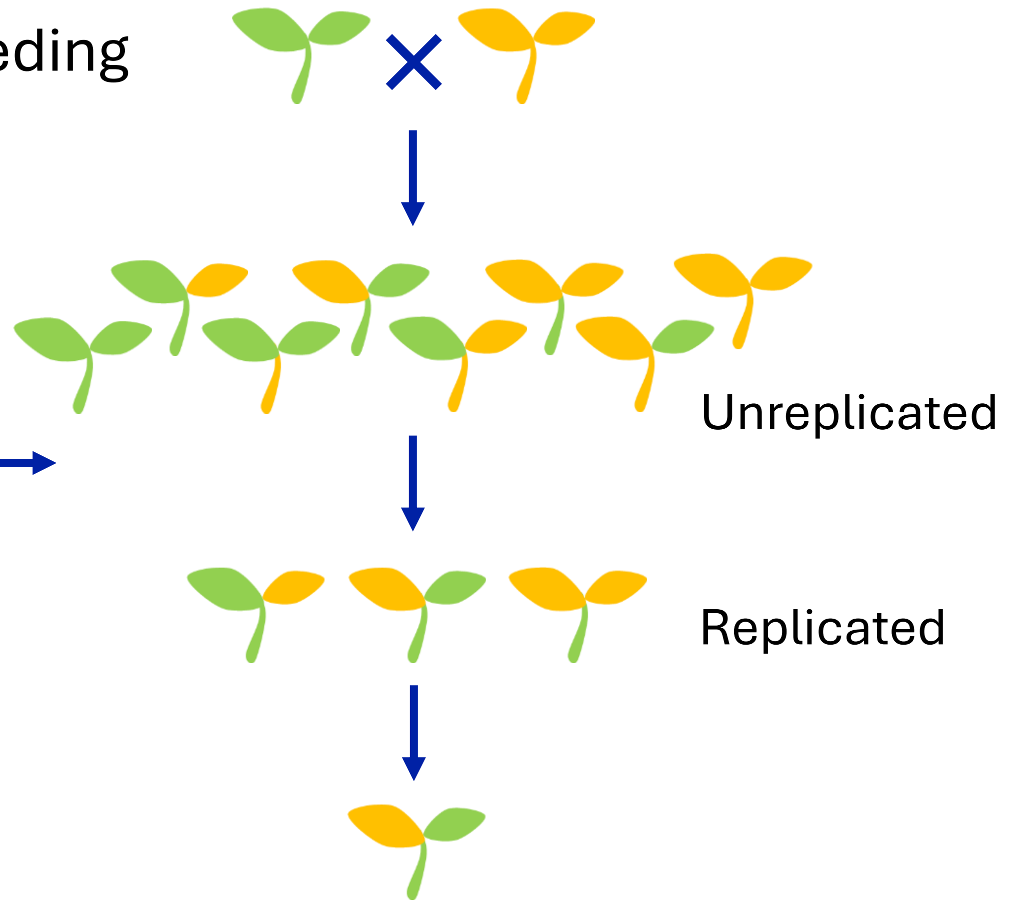


Breeding strategy

Source	Accessions
Cross	Pollination
Test	Phenotyping
Select	Speed

Phenomic selection
Genomic selection

Clonal breeding



Extension vision

- Generate new knowledge.
- Give back to the local community.

Knowledge in tropical fruit crops

Diversity in:

- Genetics
- Phenotypic traits
- Nutritional qualities
- Medicinal properties
- Cultural/ethnobotanical uses

Redland market village

Tropical fruit and spice park

Knowledge in tropical fruit crops

Diversity in:

- Genetics
- Phenotypic traits
- Nutritional qualities
- Medicinal properties
- Cultural uses

Targets

Breeding

- Improved cultivar
- Management practices

Local growers

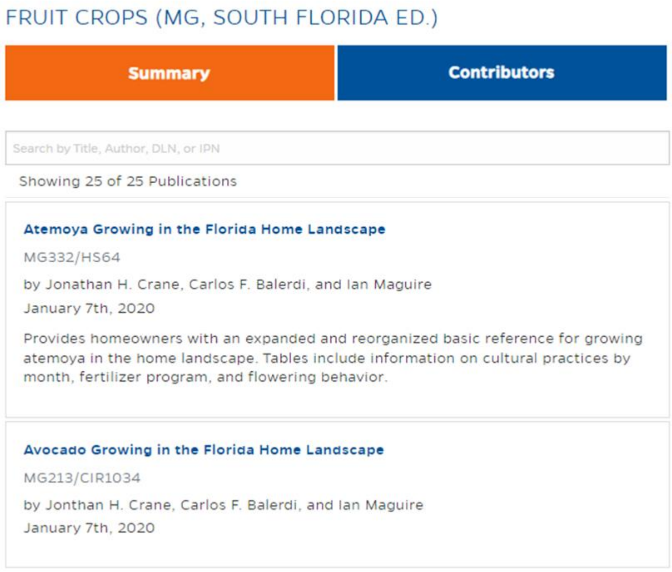
Quality produce

Local consumers

Wider market

Plans

1. Contribute to extension publications, e.g. Ask IFAS, eXtension.org, etc.
2. Provide trainings to extension agents.
3. Apply for extramural funding, e.g. federal (NIFA), local commodity group.
4. Participate/organize extension outreach events, e.g. workshops, seminars.
5. Contribute to training programs for local growers.
6. Provide technology transfer opportunities.
7. Design breeding programs based on growers' inputs, e.g. participatory plant breeding.
8. Describe our research projects in group website and social media.



https://edis.ifas.ufl.edu/collections/mg_s_fruit_crops

Teaching vision

- Engage in IFAS land-grant mission: Research, Teaching, Extension.
- Impart learning skills to students.
- Support mentees toward research independence and excellence.

Teaching experience

2013: Teaching assistant for General Genetics, University of Wisconsin-Madison.

2021/2024: Guest lecturer for Int'l Master in Plant Genetics, Genomics and Breeding, CIHEAM Zaragoza.

2022: Guest lecturer for Genetic Improvement of Crops, University of Edinburgh.

Now: Developing module on Horticulture Biotechnology I (3rd year BSc in Horticulture).

Now: Developing module on Plant Biotechnology (MSc in Applied Plant Science).

Methods: combinations of lecture, discussion and practical (in-person/online).

Teaching approaches

Impart learning skills to students.

- *Adapt* teaching style and course contents to overall/individual needs.
- *Analogize* teaching materials using clear examples.
- *Assess* learning progress, students' needs and interests.

Cultivate a comfortable and enjoyable learning environment for every student.

Mentoring experience

1. Fine-mapping of *etb1.2*, a QTL regulating ear internode length in maize and teosinte, 2013; Jordan M.
2. Mapping prolificacy QTL in maize and teosinte, 2015-2016; Lexi C.
3. QTL mapping of domestication traits in the teosinte nested association mapping population, 2015-2018; Aria P, Bailey S, Brandon K, Craig D, Isaac B, Jack S, Joe P, Kyle K, Laura B, Lora D, Michael N, Sam L.
4. Genetics of sexual determination in maize/teosinte terminal lateral inflorescence, 2016; Amanda M.
5. Perennial ryegrass under speed vernalization and speed breeding conditions, 2023-2024; Leontien H.
6. Rapid domestication of purslane in a vertical farm environment, 2023-2027; Emma I.

JOURNAL ARTICLE

Mapping Prolificacy QTL in Maize and Teosinte FREE

Liyan Yang, Chin Jian Yang, Qi Cheng, Wei Xue, John F. Doebley Author Notes

Journal of Heredity, Volume 107, Issue 7, 2016, Pages 674–678,
https://doi.org/10.1093/jhered/esw064
Published: 22 September 2016 **Article history** ▾

The genetic architecture of the maize progenitor, teosinte, and how it was altered during maize domestication

Qiuyue Chen, Luis Fernando Samayoa, Chin Jian Yang, Peter J. Bradbury, Bode A. Olukolu, Michael A. Neumeyer, Maria Cinta Romay, Qi Sun, Anne Lorant, Edward S. Buckler, Jeffrey Ross-Ibarra, James B. Holland, John F. Doebley

Version 2 Published: May 14, 2020 • https://doi.org/10.1371/journal.pgen.1008791

RESEARCH ARTICLE | BIOLOGICAL SCIENCES

The genetic architecture of teosinte catalyzed and constrained maize domestication

Chin Jian Yang, Luis Fernando Samayoa, Peter J. Bradbury, Bode A. Olukolu, Wei Xue, Alessandra M. York, Michael R. Tuholski, Weidong Wang, Lora L. Daskalska, Michael A. Neumeyer, Jose de Jesus Sanchez-Gonzalez, Maria Cinta Romay, Jeffrey C. Glaubitz, Qi Sun, Edward S. Buckler, James B. Holland, and John F. Doebley +13 Authors Info & Affiliations

Contributed by John F. Doebley, January 28, 2019 (sent for review December 14, 2018; reviewed by Loren H. Rieseberg and Bruce Walsh)

March 6, 2019 | 116 (12) 5643-5652 | https://doi.org/10.1073/pnas.1820997116

JOURNAL ARTICLE

TeoNAM: A Nested Association Mapping Population for Domestication and Agronomic Trait Analysis in Maize FREE

Qiuyue Chen, Chin Jian Yang, Alessandra M York, Wei Xue, Lora L Daskalska, Craig A DeValk, Kyle W Krueger, Samuel B Lawton, Bailey G Spiegelberg, Jack M Schnell, Michael A Neumeyer, Joseph S Perry, Aria C Peterson, Brandon Kim, Laura Bergstrom, Liyan Yang, Isaac C Barber, Feng Tian, John F Doebley
Author Notes

Genetics, Volume 213, Issue 3, 1 November 2019, Pages 1065–1078,
https://doi.org/10.1534/genetics.119.302594
Published: 01 November 2019 **Article history** ▾

Chapter 2

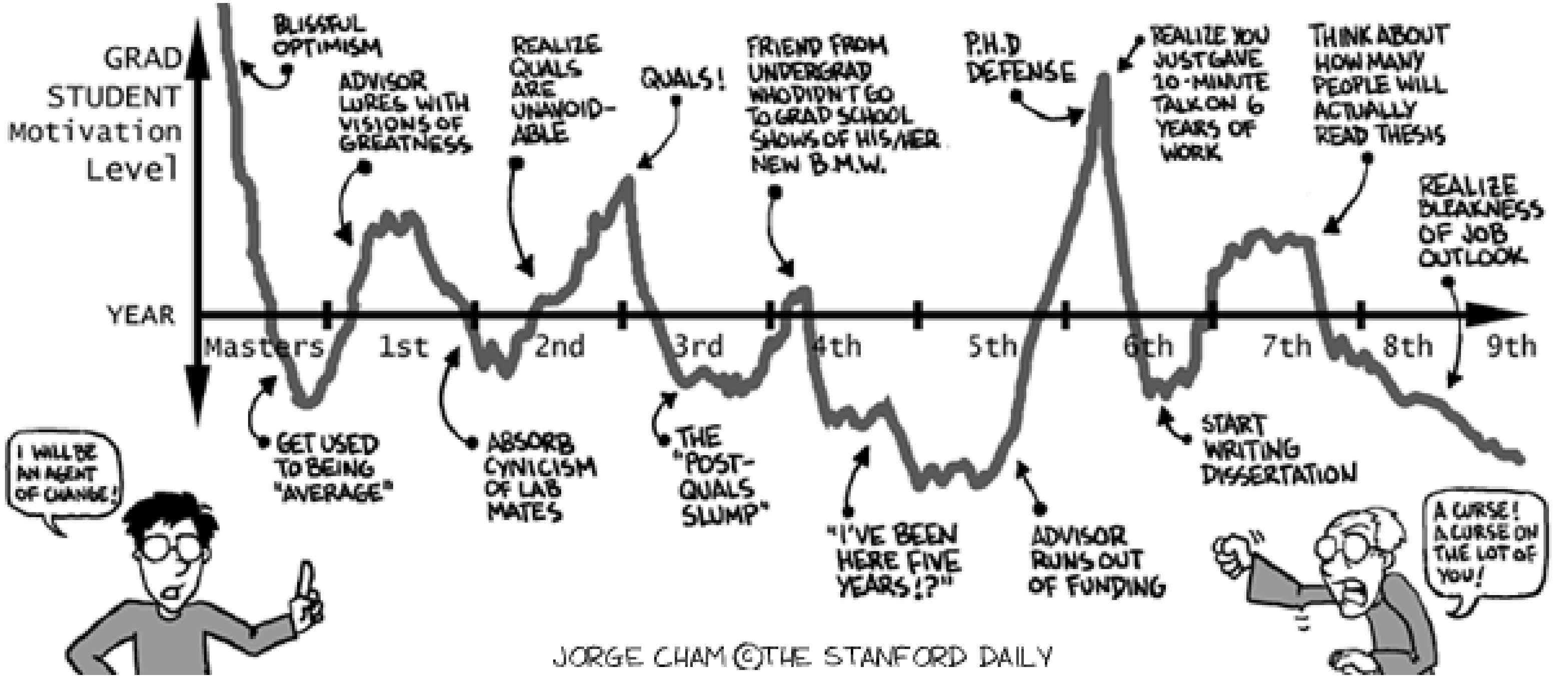
Genetic Regulation of Male-to-Female Conversion of the Terminal Lateral Inflorescence and Related Traits in Maize during Domestication

Authors: Chin Jian Yang; Amanda Alves de Melo; Joseph S. Perry; Kyle W. Krueger; Liyan Yang; John F. Doebley

Mentoring approaches

Support mentees toward research independence and excellence.

1. Understand their research interest.
2. Provide sufficient background and training.
3. Be available.
4. Be supportive.



https://phdcomics.com/comics/archive.php?comicid=125

Summary

- Wrap-up of today’s talk.

Summary

Experience

Plant breeding and genetics

- Domestication
- Genomic selection
- Breeding program

Vision

Research: QG, simulation, state-of-the-art

Breeding: demand-driven, continuity, innovation

Extension: knowledge exchange

Teaching: learning skills, independence

Summary

Experience

Plant breeding and genetics

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- Breeding program

Vision

Research: QG, simulation, state-of-the-art

Breeding: demand-driven, continuity, innovation

Extension: knowledge exchange

Teaching: learning skills, independence

Activities

- Research directions
- Breeding work
- Securing funding
- Developing collaboration
- Results dissemination
- Stakeholder engagement
- Training

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<u>Wisconsin + Others</u>
John Doebley
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NSF National Science Foundation
SSCR Scottish Society for Crop Research
IAEA International Atomic Energy Agency
UK Crop Diversity Bioinformatics HPC Resource
Field Spectroscopy Facility Natural Environment Research Council

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