PLANT BREEDING & GENOMICS

How to Investigate Breeding Priorities Using Socioeconomic Methods

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RosBREED

Enabling marker-assisted breeding in Rosaceae

How to Investigate Breeding Priorities Using Socioeconomic Methods

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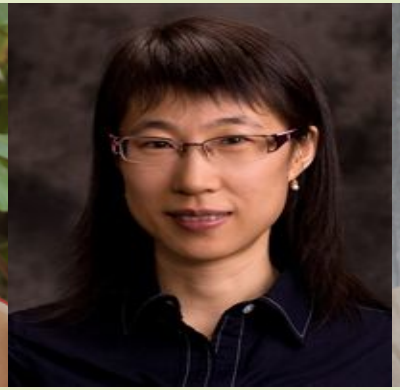
Socio Economic Team Members


Karina Gallardo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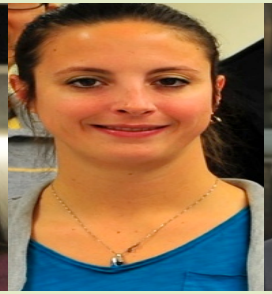
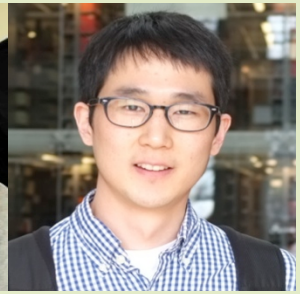
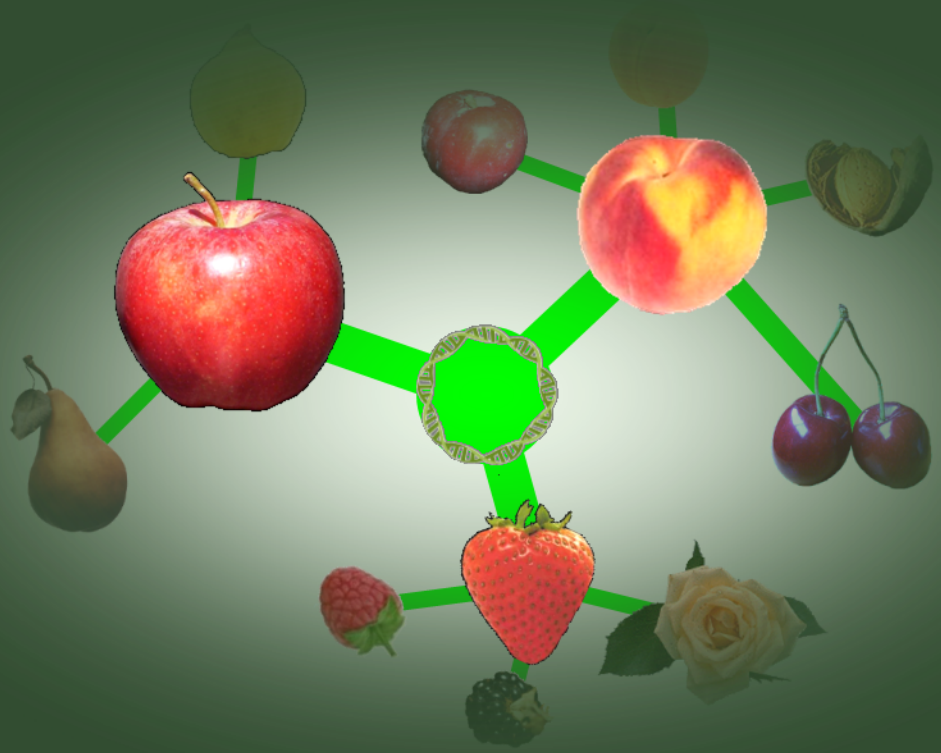

Alicia Rihn


Jong Choi


Shuoli Zhao

Outline of Presentation

- RosBREED & Socio-economics
- Breeders' survey
- Data analysis
- Conclusions & implications



RosBREED & Socio-Economics

by R. Karina Gallardo

RosBREED Mission Statement

To develop and apply marker-assisted breeding, based on improved knowledge of industry value and consumer preferences, to accelerate and increase the efficiency of rosaceous cultivar release and successful cultivar adoption

Amy Iezzoni, MSU

Cameron Peace, WSU

4 yrs
$7.2M federal
$7.2M matching

United States Department of Agriculture
National Institute of Food and Agriculture

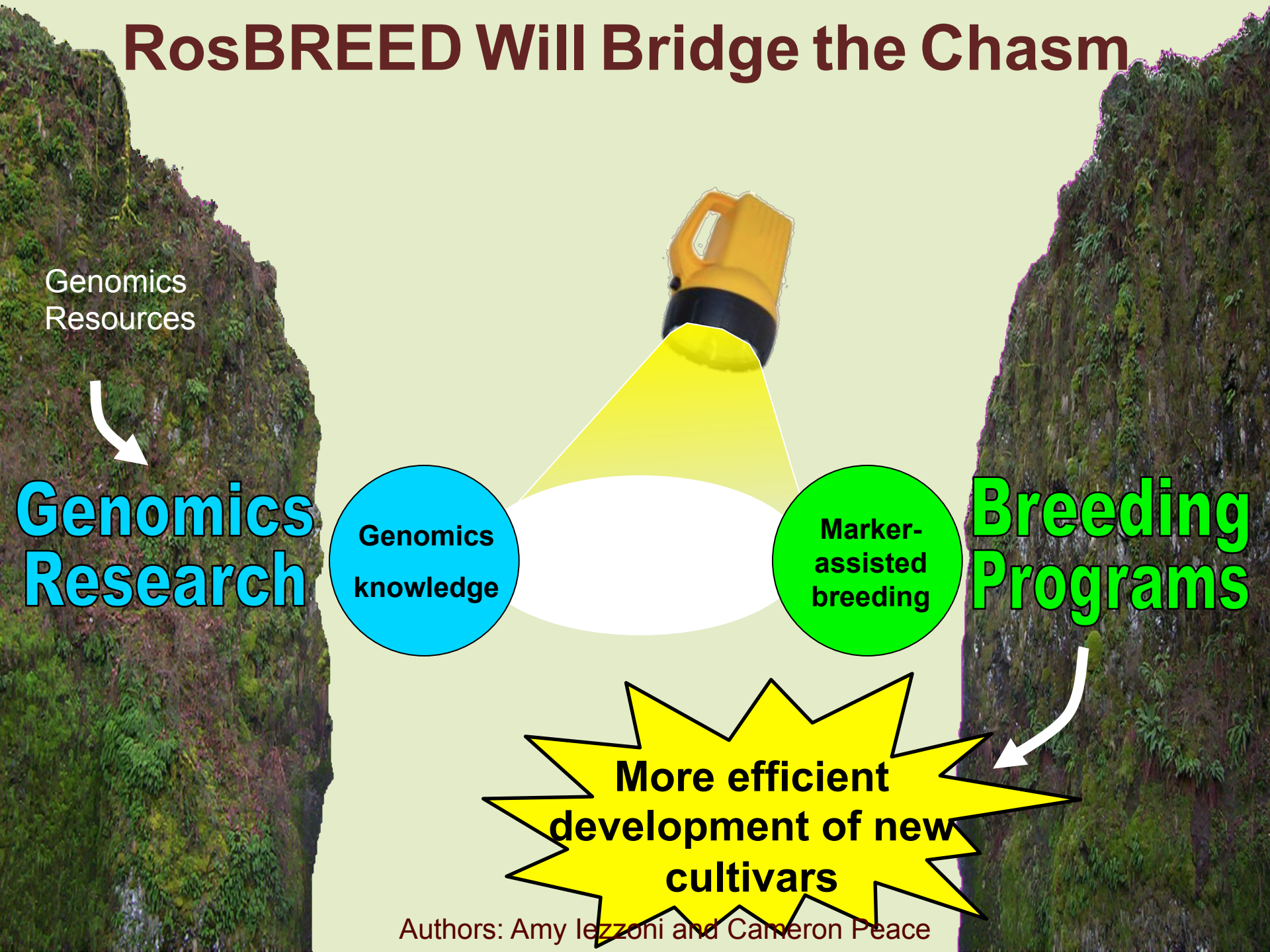
NIFA

This project is supported by the Specialty Crop Research Initiative of USDA's National Institute of Food and Agriculture

RosBREED
Enabling marker-assisted breeding in Rosaceae

www.rosbreed.org

RosBREED Will Bridge the Chasm



Authors: Amy Iezzoni and Cameron Peace

Socio-Economics Team Goal

Help accelerate and increase efficiency of cultivar development and adoption by identifying valuable breeding trait targets.

- Objectively identify important breeding trait targets.
- Prioritize the most valuable target traits for marker-assisted breeding development.

Authors: Amy Iezzoni and Cameron Peace

What trait is my next breeding target?

We like disease resistant apple trees!

We like firm tart cherries that pit well!

I like tasty strawberries!

Breeder survey 2010

Producer survey Fall 2011/ Winter 2012

Market Intermediary survey Spring 2011

Household data analysis 2010; consumer survey 2012

Trait Values

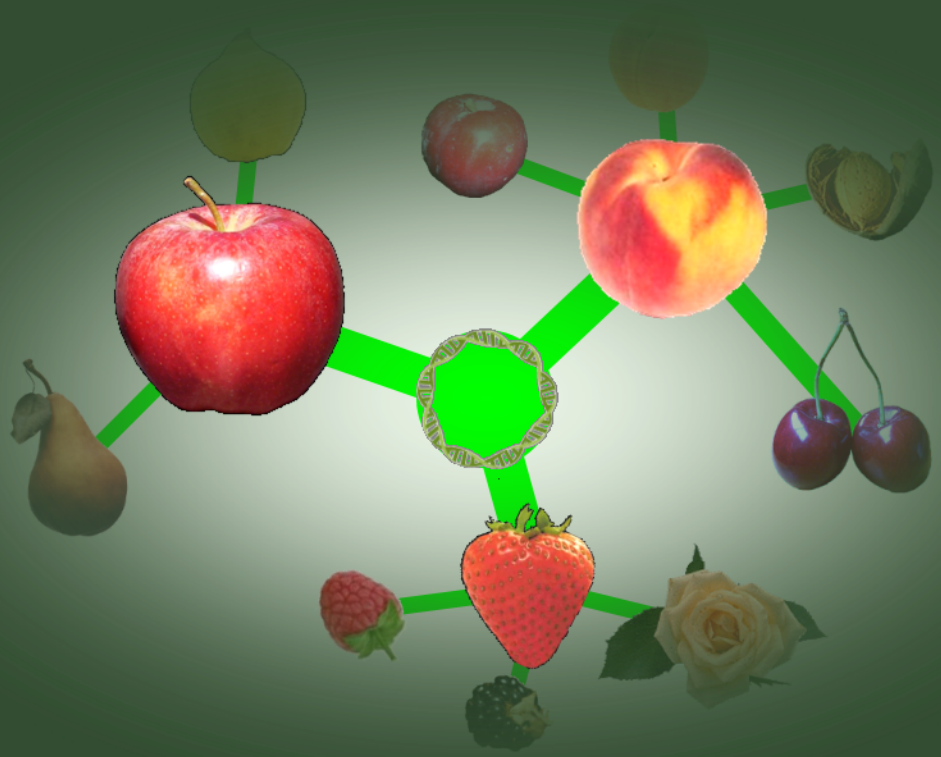
RosBREED

Enabling marker-assisted breeding in Rosaceae

www.rosbreed.org

Objective of this Webinar

This webinar will explore the application of survey data to determine how breeding targets are prioritized within Rosaceous breeding programs.



Breeders' Survey

by R. Karina Gallardo

Breeders' Survey

- No previous studies on this specific issue.
  - *Related studies Frey 1996, Fuglie and Walker 2001, Fuji et al. 2007.*
- No scientific literature to assess how rosaceous breeders establish priorities.
  - *Conflicting supply chain parties' priorities.*

Objective of the Breeders' Survey

- To improve understanding of how breeders evaluate the importance of traits.

- To provide a baseline for the larger study.
  - Compare priorities assigned by rosaceous crop breeders and by supply chain parties.

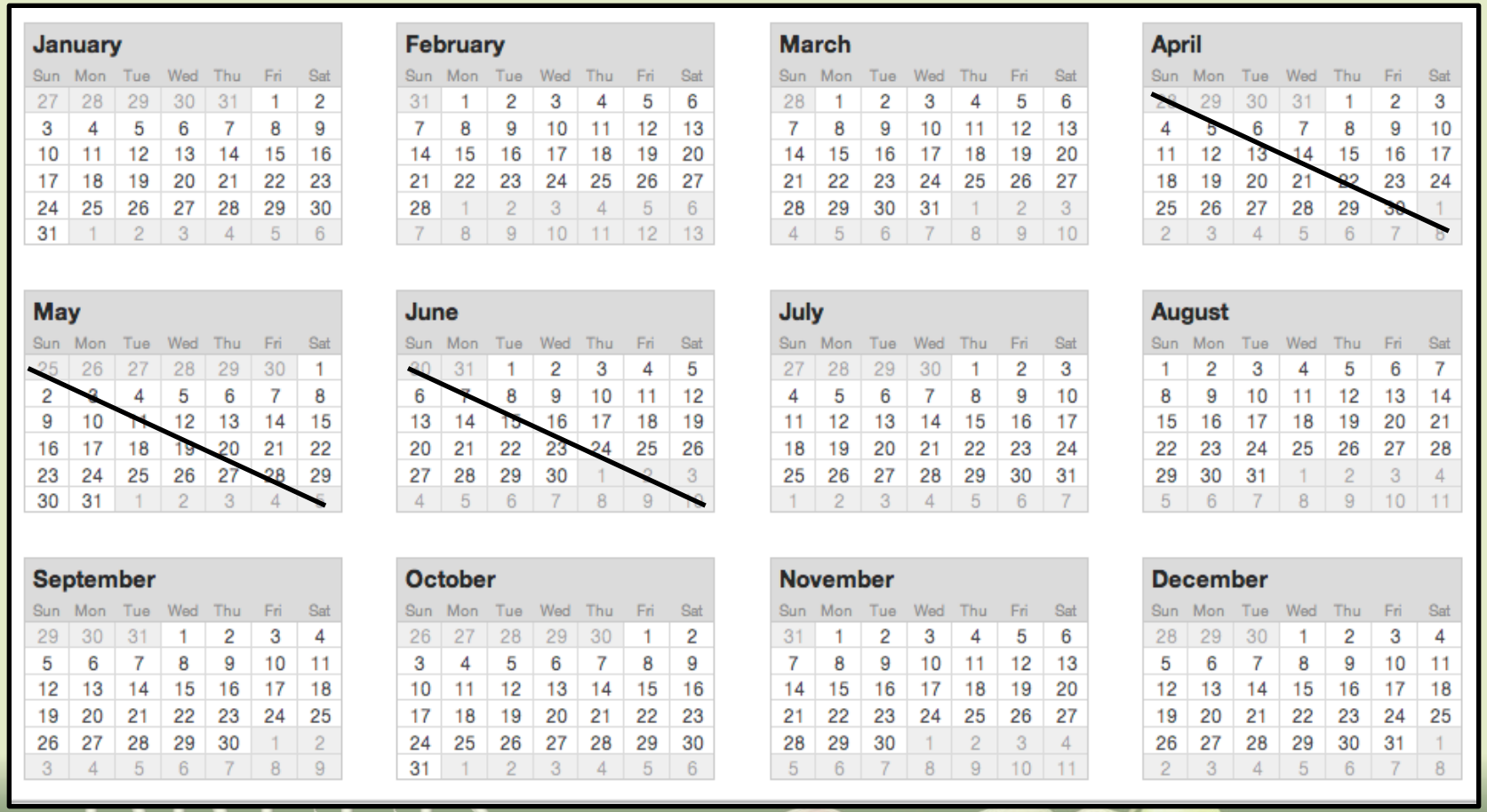
Pre - Survey

Goal: To reduce the traits for each crop to around 50.

Crop	Strawberry			
Use	Fresh Market	Fresh and Ornamental (day neutral with novel flower colors)	Primarily Fresh Market	Primarily Processed Market (frozen, juice, dried, freeze-dried). Note that growers usually sell to a processor who pre-process the berry, and then sell to other processors who make the final product. Some (about 10%) Fresh Market
Traits	1. Flavor 2. Shelf Life 3. Yield 4. Size 5. Color	1. Fruit Quality a. Size b. Shape c. Color d. Flavor e. Fragrance f. Sweetness g. Acidity h. Texture i. Anti-Oxidant content 2. Disease Resistance 3. Favorable Flowering Habit 4. Flower Color	Note – 1-3 were listed as important traits 1. Productivity a. Yield/plant (weight) b. Overall number of fruit per plant c. Overall size of plant 2. Fruit Shape – symmetric 3. Firmness Note- 4-6 were listed as traits he is trying to improve: 4. Fruit color – external	Fruit Traits 1. Intense flavor 2. Intense red color – internal and external 3. Optimal size for harvesting 4. High Brix 5. Moderate runnering 6. High TA acidity 7. Low pH 8. Low drip loss 9. Uniform Shape Production Trait and Other 1. Short day types 2. Ever bearing

Survey Sample Population

During April to June of 2010, we conducted a comprehensive internet survey of **60** rosaceous breeding programs in the U.S. and Canada.



Survey Response Rate

- We obtained **35** complete responses (**58% response rate**) from Rosaceous breeding programs whose target crops are:
  - *Apple scion and rootstock*
  - *Apricot scion*
  - *Cherry scion (sweet and tart)*
  - *Peach scion*
  - *Pear scion*
  - *Blackberry, red raspberry, strawberry, and*
  - *Rose.*

Survey Focus

- To reduce complexity, we focused our analysis on **fruit scion** breeding programs.
  - *We did not consider programs addressing rootstock (one response) and rose (two responses).*
  - *This reduced the sample size from 35 to 32 usable responses.*

Responses Used

- Out of the 32 responses, we ended up using 24,
  - *8 programs in strawberry, 8 in peach, 4 in apple, and 4 in red raspberry.*

Survey Questions - Section 1

3. How many years have you worked as a breeder?

4. What type of organization are you working at as a breeder?

- Private sector
- University
- Federal
- Other, please specify:

5. In 2009, how many full-time equivalent staff (breeders, scientific assistants, non-scientific s
your program?

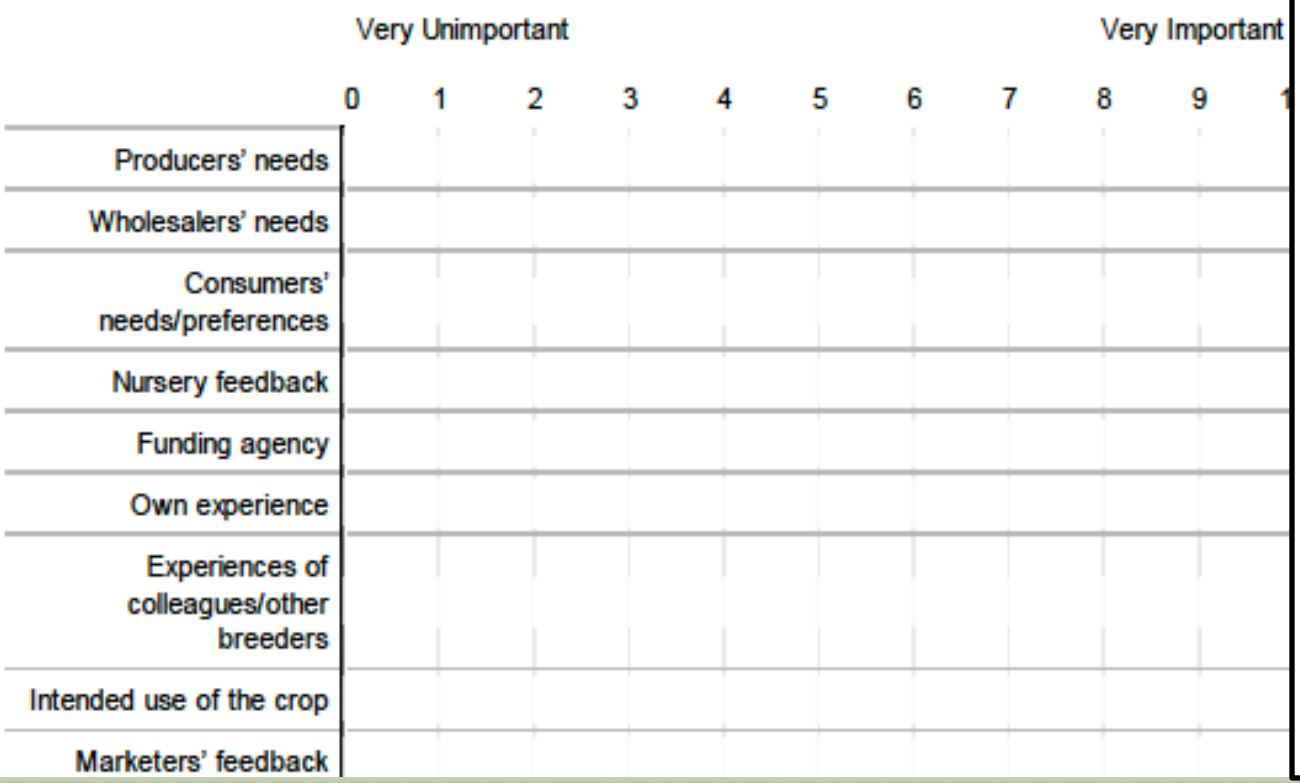
Breeders (excluding yourself)	
Scientific assistants	
Non-scientific staff	
Graduate students	
Post-doc	
Other, please specify:	

First section: Background information of the breeding program, e.g., main crop bred, main use of the target crop (fresh or processed market), years of experience of the breeder leading the program, and so on.

Survey Questions - Section 2

SETTING PRIORITIES

6. Using the scale bars, please rate on a 0-10 scale the importance of INTERESTED PARTIES that influence your setting of priorities when selecting a trait for inclusion in your breeding program (0=very unimportant, 10=very important). For each row, put the cursor at the number you think that best matches your rating and left click. After you click the bar, it will turn blue. Only blue bars will be recorded.



Second section: Considerations influencing priorities when selecting a trait for inclusion in the breeding program: *interested parties.*

Survey Questions - Section 2 (cont. a)

7. Using the scale bars, please rate on a 0-10 scale the importance of TECHNICAL CONSIDERATIONS that influence your setting of priorities when selecting a trait for inclusion in your breeding program (0=very unimportant, 10=very important). Put the cursor at the number you think that best matches your rating and click. After you click the bar, it will turn blue. Only blue bars will be recorded.

	Very Unimportant 0	1	2	3	4	5	6	7	8	Very
Environmental effects on trait expression										
Availability of genetic variation for the trait										
Availability of resources										
Availability of expertise										
Previous research done by others/publications										
Other, please specify:										
Other, please specify:										

Second section: Considerations influencing priorities when selecting a trait for inclusion in the breeding program: *technical considerations*.

Survey Questions - Section 2 (cont. b)

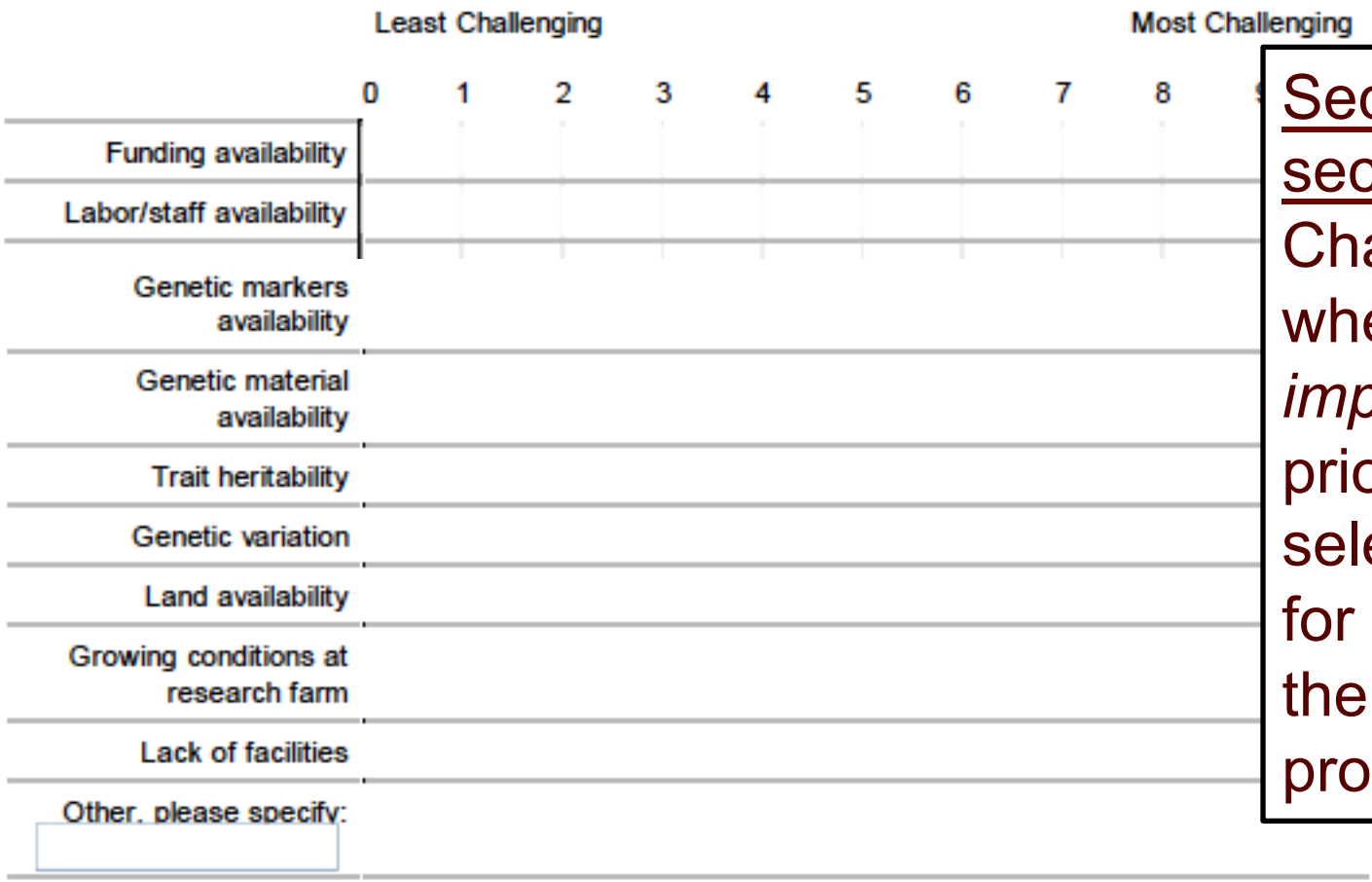
10. Using the scale bars, please rate on a 0-10 scale the challenges you face when DETERMINING your priorities (10=most challenging and 0=least challenging). Put the cursor at the number you think that best matches your rating and click. After you click the bar, it will turn blue. Only blue bars will be recorded.

	Least Challenging 0 1 2 3 4 5 6 7 8 9 10 Most Challenging
Lack of consistent /standardized information on genetic material	
Lack of genetic material	
Lack of consistent/standardized information on methods	
Poor communication with interested parties	
Separate short-term from long-term needs	
Difficult to find consensus across interested parties	
Uncertainty if variety being developed would be commercially viable	
Other, please specify:	

Second section: Challenges when *determining* priorities when selecting a trait for inclusion in the breeding program.

Survey Questions - Section 2 (cont. c)

11. Using the scale bars, please rate on a 0-10 scale the challenges you face when IMPLEMENTING your priorities (10=most challenging and 0=least challenging). Put the cursor at the number you think that best matches your rating and click. After you click the bar, it will turn blue. Only blue bars will be recorded.



Second section: Challenges when *implementing* priorities when selecting a trait for inclusion in the breeding program.

Survey Questions - Section 3

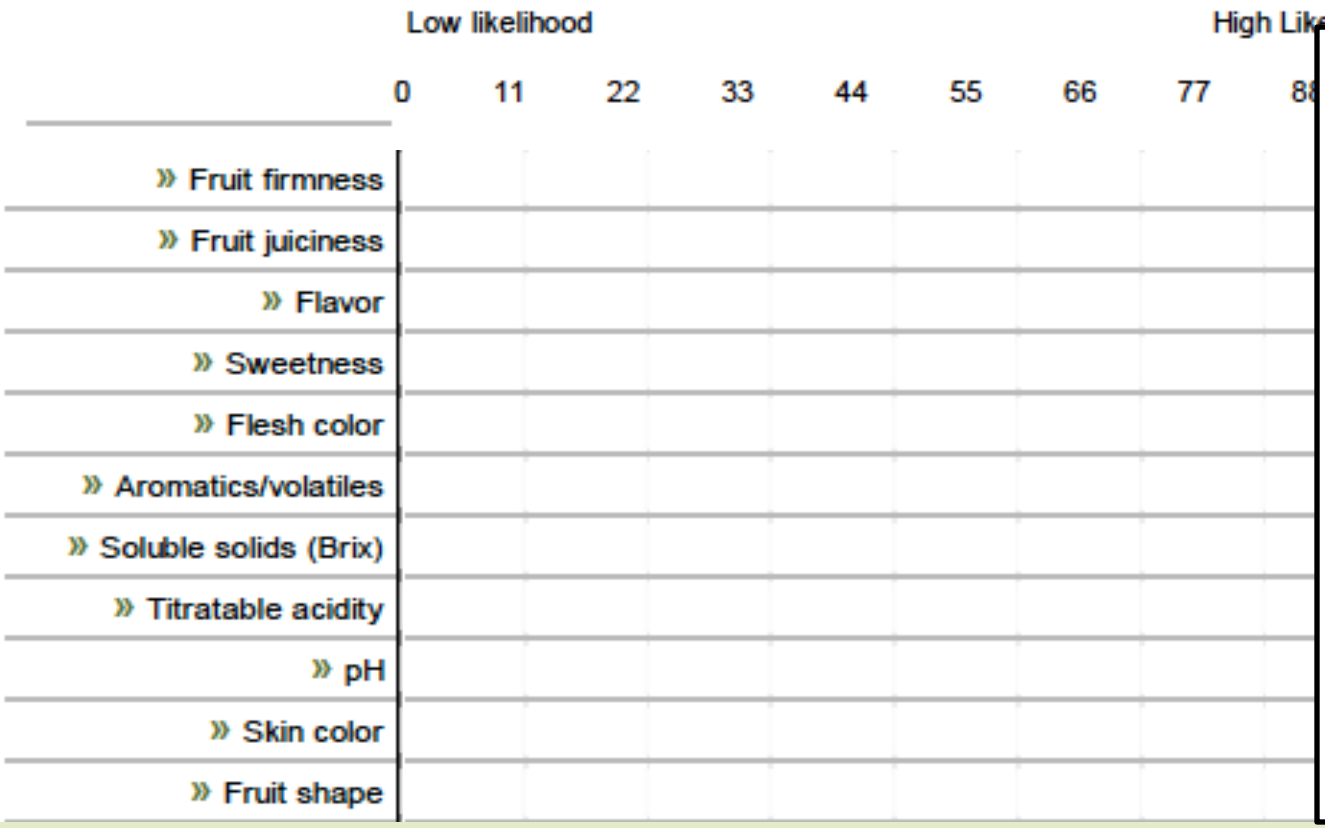
19A. What traits are you currently working to improve? Please circle the level of importance of each trait. If the trait is not relevant to your crop, please choose "Not applicable."

	Very Unimportant	Unimportant	Neutral	Important	Very Important	Not Applicable
Fruit firmness	○	○	○	○	○	○
Fruit juiciness	○	○	○	○		
Flavor	○	○	○	○		
Sweetness	○	○	○	○		
Flesh color	○	○	○	○		
Aromatics/volatiles	○	○	○	○		
Soluble solids (Brix)	○	○	○	○		
Titratable acidity	○	○	○	○		
pH	○	○	○	○		
Skin color	○	○	○	○		
Fruit shape	○	○	○	○		
Fruit size	○	○	○	○		
Fruit uniformity	○	○	○	○		
Surface texture	○	○	○	○		

Third section: Breeders' ratings of importance of various fruit trait (0-5 scale, 0=very unimportant, 5=very important).

Survey Questions - Section 3 (cont.)

You rated the following traits as "Very Important." Using the following 0-100 scaling bars, please specify the likelihood you will select these traits as your breeding targets (0=low likelihood, 100=high likelihood). Please place the cursor at the number that best matches your likelihood of breeding and click. After you click the bar, it will turn blue. Only blue bars will be recorded.



Third section: Likelihood breeders would select for each trait (on a 1-100 scale, 0=lowest likelihood, 100=highest likelihood).

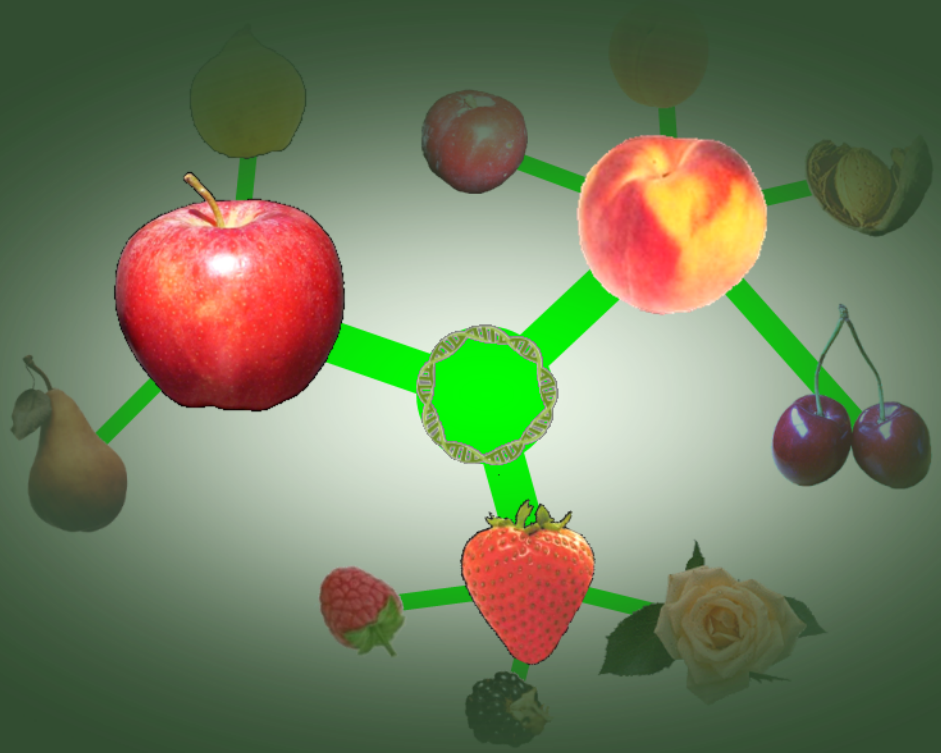
Preamble to Data Analysis

- The analysis was complicated by the large number of individual traits selectable for one each crop.

We aggregated individual traits for meaningful econometric analysis based on the expert opinion of a breeder using the criterion of similar contributions to fruit or plant characteristics.

Preamble to Data Analysis (cont.)

- We refer to the aggregated traits as **trait clusters**:
  - *Fruit texture*
  - *Fruit flavor*
  - *Fruit appearance*
  - *Biotic resistance*
  - *Abiotic resistance*
  - *Plant habit*
  - *Yield season*
  - *Postharvest quality*
  - *Phytonutrient content*



Breeder's Survey Data Analysis

by Huixin Li

Model

- We used a double-bounded Tobit model to analyze the factors that affect breeders' likelihood for selecting a trait (*Y*).

$$Y = \begin{cases} 0 & if \quad Y^* \le 0 \\ y^* & if\, 0 < Y^* < 100 \\ 100 & if Y^* \ge 100 \end{cases}$$

The Tobit model allows censoring in both tails of the probability distribution of the dependent variable.

Model

- The dependent variable (*Y*) is the likelihood of selection for trait clusters,

$$Y_i^* = X_i\beta + \varepsilon_i$$

Y_i^* is a latent variable that is observed for values within the (0,100) range.

X_i is the vector of explanatory variables including: (1) rating for the supply chain considerations influencing breeders' priorities, (2) ratings for challenges when determining priorities for selection, (3) years of experience of the breeder leading the program, (4) binary variable for the use of MAB at the breeding program; (5) binary variable for region where the program is located, (6) binary variable for the use of the target crop in the program (fresh or processed market), (7) binary variable to indicate the main crop in the program.

β is the vector of parameters to be estimated and ε_i is the error term.

Coding in SAS®

- The analysis was done using the SAS® software
- Dependent variable: Likelihood (0-100)
- Independent variables:
  - Ratings for supply chain considerations: *Party1 Party2 Party3 Party5 Party6 Party8 Party9 Party10.*
  - Ratings for the challenges: *Lack detchallenge4 detchallenge5 detchallenge6 detchallenge7.*
  - Years of the breeder's experience: *Experience.*
  - Use of marker assisted breeding: *MAB*
  - Region where program is located: *Pacific California Midwest Northeast Southeast Canada.*
  - Use of the target crop (fresh market): *Fresh*
  - Main crop in the program: *Apple Strawberry Peach RedRasp*

Model - Variable Explanation

Variable	*Survey question*	*Description*
Party1	Q6	Producers' needs
Party2	Q6	Wholesalers' needs
Party3	Q6	Consumers' needs / preferences
Party5	Q6	Funding agency
Party6	Q6	Own experience
Party8	Q6	Intended use of the crop
Party9	Q6	Marketers' feedback
Party10	Q6	Retailers' feedback

Model - Variable Explanation (cont.)

Variable	*Survey question*	*Description*
detchallenge1	Q10	Lack of information on genetic material
detchallenge2	Q10	Lack of genetic material
detchallenge3	Q10	Lack of information on method
detchallenge4	Q10	Poor communication with interested parties
detchallenge5	Q10	Separate short-term from long-term needs
detchallenge6	Q10	Difficult to find consensus across interested parties
detchallenge7	Q10	Uncertainty if variety being developed would be commercially viable

Data Analysis - SAS® Code

Code:

```
/*Dataset is trait.sas7bdat */
/*Dependent variable is Likelihood*/
/*Independent variables are listed in varlist */
/*Tobit model is used to do the estimation */
```

About the Code - Comments

- It is good style to comment your programs.
- You can use the comment statement anywhere in a SAS® program.
- SAS® will ignore the text in comments during execution.
- Syntax: *text; /*text*/

SAS® Code

```
/*Retrieve and organize the data*/

libname datapath "I:\tobit paper";
data work.trait;
set datapath.trait;
lack = (detchallenge1 + detchallenge2
+detchallenge3) / 3;
run;
```

About the “Libname” Command

- Use permanent SAS data sets with Libname statement.
- Define: libname datapath "I:\tobit paper";
- Use: datapath.traits

SAS® Data Step

- Data steps start with the DATA statement
- Followed by a name you make up for a SAS® dataset
- You can create or redefine variables with assignment statements.

SAS® Code

```
/*The list of independent variables*/

%let varlist =
Party1 Party2 Party3 Party5 Party6
Party8 Party9 Party10
lack detchallenge4 detchallenge5 detchallenge6
detchallenge7 Experience MAB Fresh
Pacific California Midwest Northeast
Southeast Canada
Apple Strawberry Peach RedRasp;
```

SAS® Code (cont.)

```
data apple;
set trait;
if apple = 1;
run;

proc means data=apple;
var rank likelihood ;
by clusterT;
run;
```

The Means Procedure

- Proc means provide simple statistics (mean, SD, min, max) on numeric variables.
- VAR statement specifies which variables to use in the analysis.
- BY statement performs separate analysis for each level of the variables in the list.

Proc Means Output

The SAS System

The MEANS Procedure

ClusterT=T1

Variable	N	Mean	Std Dev	Minimum	Maximum
Rank	14	4.8571429	0.3631365	4.0000000	5.0000000
Likelihood	14	89.8571429	14.4427631	60.0000000	100.0000000

ClusterT=T2

Variable	N	Mean	Std Dev	Minimum	Maximum
Rank	32	4.3125000	0.9310937	2.0000000	5.0000000
Likelihood	29	74.5862069	22.7557171	0	100.0000000

SAS® Code

```
proc sort data=trait;
by clusterT;
run;

proc qlim data = work.trait;
        by clusterT;
        model likelihood = &varlist ;
        endogenous likelihood ~ censored(lb=0  ub =
100);
run;quit;
```

The QLIM Procedure in SAS®

- The QLIM (qualitative and limited dependent variable model) procedure analyzes limited dependent variable models.
- The Tobit model can be specified with the CENSORED option in ENDOGENOUS statement.
- The bounds must be specified for the censored variable.

Proc QLIM Output

ClusterT=T1

The QLIM Procedure

Summary Statistics of Continuous Responses

Variable	Mean	Standard Error	Type	Lower Bound	Upper Bound	N Obs Lower Bound	N Obs Upper Bound
likelihood	72.67442	27.521629	Censored	0	100	2	21

Model Fit Summary

Number of Endogenous Variables	1
Endogenous Variable	likelihood
Number of Observations	129
Missing Values	8
Log Likelihood	-522.27225
Maximum Absolute Gradient	0.0000122
Number of Iterations	131
Optimization Method	Newton-Raphson
AIC	1101
Schwarz Criterion	1181

Algorithm converged.

Proc QLIM Output (cont.)

Parameter Estimates

Parameter	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	-7.633647	82.073778	-0.09	0.9259
Party1	1	15.046650	7.266755	2.07	0.0384
Party2	1	-5.990506	2.905130	-2.06	0.0392
Party3	1	3.010886	6.611582	0.46	0.6488
Party5	1	2.882913	2.486217	1.16	0.2462
Party6	1	-0.104691	4.637829	-0.02	0.9820
Party8	1	-5.104112	4.590902	-1.11	0.2662
Party9	1	8.141696	4.528489	1.80	0.0722
Party10	1	-6.994701	4.967241	-1.41	0.1591
lack	1	-7.495478	3.332263	-2.25	0.0245
detchallenge4	1	-3.568662	2.951190	-1.21	0.2266
detchallenge5	1	1.683458	2.653359	0.63	0.5258
detchallenge6	1	3.200346	2.723413	1.18	0.2399
detchallenge7	1	0.698723	2.337953	0.30	0.7650
Experience	1	0.448975	0.592002	0.76	0.4482
MAB	1	10.223858	21.793737	0.47	0.6390

Results

Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Intercept	–7.63	73.60	11.56	–125.55	–99.76	–57.04	1.57	–189.21	–153.47
Interested parties									
Producers	15.05**	–12.14**	5.03	–3.98	0.91	4.20	–7.43	14.21**	18.26***
Wholesalers	–5.99**	1.62	–1.68	1.44	–3.84	–7.41***	–0.34	–5.57**	–7.98***
Marketers	8.14*	3.35	3.30	4.57*	5.14	6.46	8.70**	3.19	8.47**
Retailers	–7.00	4.45	–0.52	–0.37	–3.22	0.28	–4.36	8.51**	–4.51

Results (cont.)

Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Interested parties									
Consumers	3.01	10.89**	4.33	13.75***	15.23***	10.53**	10.45**	0.63	–1.19
Funding agency	2.88	–0.03	0.20	1.02	–0.32	1.58	0.06	–5.73***	3.71**
Own experience	–0.11	1.09	0.14	2.64	–4.10	1.46	2.68	8.38**	12.77**
Own experience	–0.11	1.09	0.14	2.64	–4.10	1.46	2.68	8.38**	12.77**
Intended use of crop - Processing	–5.10	–8.33***	–2.98	–6.24**	3.67	–3.94	–6.30*	–8.33**	–11.52**

Results (cont. a)

Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Challenges faced by breeders									
Lack of g. mat., inf. methods	–7.50**	–3.29	–2.49	–0.57	0.10	–8.01**	1.12	4.19	–5.65
Poor comm. w/ int. parties	–3.57	–2.01	–2.21	–4.59**	0.64	–3.20	–5.81**	2.20	1.14
Separate s. term from l. term needs	1.68	–3.24	–0.85	1.97	1.08	3.94*	3.05	–0.80	–0.30

Results (cont. b)

Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Challenges faced by breeders									
Difficult to find consensus across interested parties	3.20	–1.31	–0.94	–0.51	–0.81	2.30	–1.28	–0.06	6.48***
Uncertainty about commercial viability	0.70	2.81*	2.96**	3.23**	1.38	2.13	2.20	–0.02	2.70

Results (cont. c)

Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Breeder leading the program									
Years of experience	0.45	1.92***	–0.11	0.39	–0.08	0.48	0.37	0.15	–0.27
Characteristics of the breeding program									
Use of MAB	10.22	8.28	–8.74	–0.32	–20.26	–0.15	–8.93	19.64	25.07
Pacific Northwest	–13.02	19.36	1.42	40.94**	8.58	–0.02	30.14	85.46***	–30.01
California	–3.08	–28.28	1.21	24.46	19.80	3.55	18.62	31.02	–0.54
Midwest	–41.18	1.61	–9.08	38.20**	–6.98	11.81	–9.14	52.91**	–50.51**
Northeast	30.26	–10.25	5.00	40.50**	34.67	36.58*	23.10	18.91	–3.86

Results (cont. d)

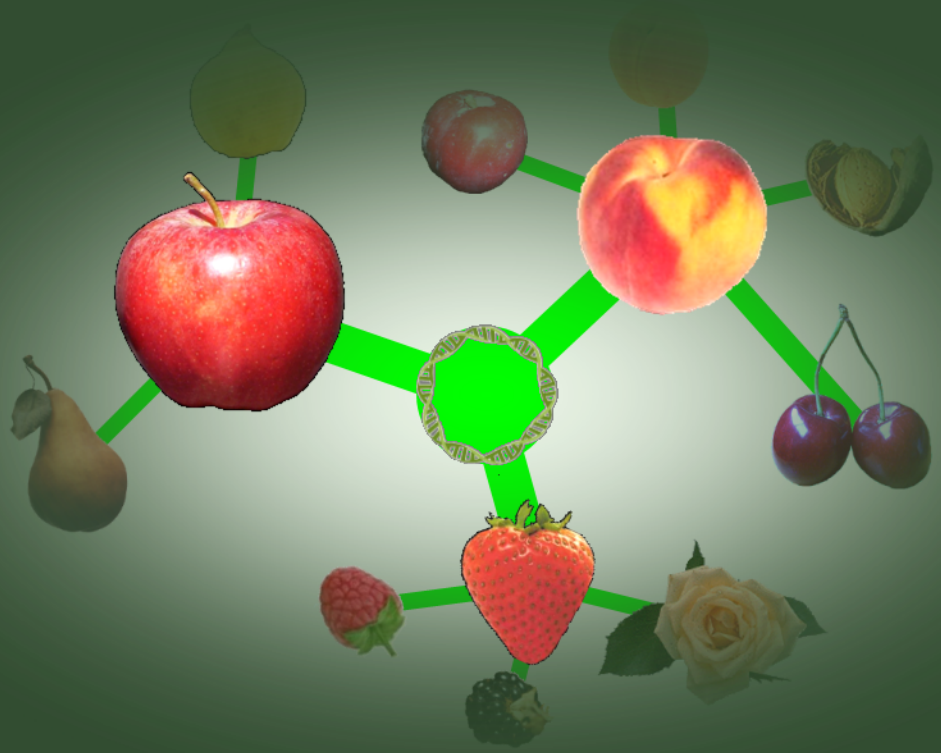
Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Southeast	14.85	46.70***	–2.95	54.32***	16.27	33.10*	31.73*	21.51	–5.98
Canada	–4.10	35.99**	14.49	57.03***	25.90	19.76	29.67	32.21*	–43.13**
Characteristics of the main crop in the breeding program									
Crop is for the fresh market	3.66	–10.30	10.39	25.93*	9.32	10.43	27.40*	39.25**	42.12**
Apple	38.29	0.98	–6.11	–17.17	–10.67	–36.73**	–21.96	–8.38	25.06**

Results (cont. e)

Parameter Estimates for the Tobit Model Analyzing the Factors Affecting Breeders' Likelihood to Select a Trait

Variable	Texture	Flavor	Appear-ance	Disease and pest resistance	Abiotic resistance	Plant habit	Yield/ Season	Post-harvest quality	Phytonu-trient content
Characteristics of the main crop in the breeding program									
Strawberry	–11.08	6.29	–3.30	11.02**	–11.15	–22.80**	1.78	36.00***	–11.05
Peach	–5.46	–4.51	9.05	–6.02	–0.96	–6.86	–3.53	0.69	6.62
Red raspberry	–6.86	19.76**	14.71**	28.44***	8.72	–2.53	0.24	61.30***	–9.23
Number of observations	*129.00*	*251.00*	*274.00*	*311.00*	*182.00*	*256.00*	*197.00*	*128.00*	*104.00*



Conclusions and Implications

by Karina Gallardo

Conclusions

- Trait clusters
  - ✓ *Useful approach to simplify the breeders' challenges to assign program priorities.*
- Consumer driven forces
  - ✓ *Positively impacted breeders' likelihood of selection for traits than did producers and breeders' own experience.*

Conclusions

- Technical challenges
  - ✓ *Negatively affected the likelihood of selecting for sensory quality and plant habit.*
- Societal challenges
  - ✓ *Negatively impact on the likelihood of selecting for the trait clusters biotic and abiotic resistance, yield/season, and phytonutrient content.*

Conclusions

- Breeding programs targeting the fresh market
  - *Higher likelihood of selection for most trait clusters in the study.*
- Complex nature of rosaceous breeding
  - *Multiple traits that impact final fruit product, profitability and production environment.*

Implications

- Initial information provided in this study
  - *Useful to recognize a smaller group of individual traits to focus on and include in further studies eliciting values from supply chain stakeholders.*
- Improve understanding from stakeholders and funding agencies
  - *Challenges faced by breeders and help align priorities with the needs of the entire supply chain.*

Acknowledgements

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

This project is supported by the Specialty Crop Research Initiative of USDA's National Institute of Food and Agriculture

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