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An Investigation of U.S. Apple Producers' Trait Prioritization—Evidence from Audience Surveys

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***Abstract*. Systematic studies of the relative importance of apple traits for U.S. apple producers to inform U.S. apple breeding programs have been lacking. To fill this gap, a series of audience surveys with instant feedback at five apple producer meetings across the United States was conducted. The traits included in this study were fruit crispness, juiciness, firmness, flavor, soluble solids concentration, sugar–acid balance, shelf life at retail, freedom from storage disorders, host plant disease resistance, and other fruit and tree traits provided by the producer. Producers rated fruit flavor and crispness as the most important traits for a successful apple cultivar. The relative importance assigned to traits was associated with growing location and producers' years of experience in the decision-making process of managing apple orchards. This study contributes directly to a larger effort that provides breeding programs with systematic knowledge of trait preferences of supply chain members, including producers, and should result in a more targeted approach to developing and commercializing new apple cultivars.**

Fresh and processed apple products are important to the human diet and contribute to the economic viability of many U.S. rural areas. From 2000 to 2010, the mean annual per-capita consumption of apples was 8 kg and the average annual production was 4.2 million tons on 152,000 ha (U.S. Department of Agriculture, 2010). Approximately 64% (2.7 million tons) of the total production was marketed as fresh and 36% (1.5 million tons) was marketed as processed. Mean annual return to producers was $0.59 per kg and $1.37 per ton for the fresh and processing markets, respectively (U.S. Department of Agriculture, 2010).

Development and commercialization of improved apple scion cultivars that meet consumer expectations are important to enhance the economic sustainability of the U.S. apple industry. Apple seedlings' long juvenility periods, the need for extensive evaluation of horticultural and postharvest traits, and the complexity of marketing a new cultivar contribute to the lengthy process from making the cross to commercialization (Barritt, 1999). The choice of cultivar is a decision with high stakes for a producer because of the cost of orchard establishment and the time lag to generate a positive cash flow (Fuglie and Walker, 2001; Galinato and Gallardo, 2012; Galinato et al., 2011; Gallardo et al., 2012; Gallardo and Galinato, 2012; Mouron et al., 2013). As a result, apple producers must select the cultivar best suited to their orchards' specific environmental conditions and marketing channels and must contemplate financial considerations such as capital access and return on investment. Furthermore, producers must consider consumers' preferences in their selection of the cultivar with the highest probability of profitability (Barritt, 1999). Apple breeding programs' impact on stakeholders could be enhanced through the development of cultivars improved for the traits of most value to all members of the supply chain (producers, market intermediaries, and consumers).

This study is part of a more comprehensive U.S. Department of Agriculture-funded project called RosBREED, whose goal is to enable the use of marker-assisted breeding in the plant family Rosaceae and thereby improve the efficiency of plant breeding programs (Iezzoni et al., 2010). Marker-assisted breeding has been successfully used in crop improvement programs (e.g., improving product quality, management practice efficiency, and product uniformity) (Dirlewanger et al., 2004; Evans et al., 2012; Iezzoni et al., 2010). Because the development and use of marker-assisted breeding require extensive genetic knowledge, trained personnel, and sufficient financial resources, it is crucial for breeders to focus on the traits of maximum value to the whole supply chain (Alpuerto et al., 2009; Luby and Shaw, 2001). Identifying these traits is challenging, and very few studies in crop plants, including those in Rosaceae, have evaluated the importance of traits to the whole supply chain (Zimmerman and Van der Lans, 2009).

Typically, rosaceous crop breeders establish partnerships with crop producers to run orchard trials of advanced selections, and most public sector programs obtain funding from producer organizations. No published research exists to clarify how specialty crop producers value fruit quality traits. This study focuses on producers' trait preferences; however, consumer demand is important to producers because the new cultivars they adopt need the fruit quality traits that consumers prefer.

Most research on the importance of apple traits has focused on consumers. Manalo (1990) concluded that consumers value apple crispness the most followed by size, color, and flavor. Daillant-Spinnler et al. (1996) found that British consumers considered apple texture and taste to be more important than aroma and appearance. Kajikawa (1998) reported that Japanese wholesale prices for apples imported from New Zealand and the United States were associated with soluble solids concentration (SSC), acidity, and juice content. Jesionkowska et al. (2006) determined that Polish consumers value flavor and juiciness the most, followed by sweetness and firmness. McCluskey et al. (2007) found that a premium of 52.80 cents per kg could be attained if apples had a firmness of at least 62.28 N and a SSC of at least 13.50 °Brix. Dinis et al. (2011) emphasized the importance of apple taste, appearance, smell, and origin to consumers' value of apples. McCluskey et al. (2013) found that consumers in the U.S. Pacific Northwest are willing to pay more for firmness in 'Red Delicious' than in 'Gala' ($1.16/lbf vs. $0.08/lbf), but are willing to pay more for sweetness in 'Gala' compared with 'Red Delicious' ($0.40 vs. $0.37).

Fruit quality traits affect consumers' preferences; hence, producers' perceptions of consumer preferences could impact their decision to select a new apple cultivar to plant. The objective of this study was to assess how apple producers from different production areas across the United States evaluate the importance of fruit quality and plant traits. This information should be useful to breeders and supply chain groups in determining the fruit quality traits to focus on when breeding new apple cultivars.

Materials and Methods

Presurvey producer interviews. Presurvey interviews were conducted with apple producers to gather a comprehensive list of fruit quality and tree traits that are important to them along with the factors that influence their adoption of new apple cultivars. We interviewed 10 apple producers, either over the phone or in-person, from each of three major (by volume) production states in the United States (Washington, New York, and Michigan). Producers were asked how they make decisions about the cultivars they choose to grow, the major use/market for their apples (fresh or processed), their sources of plant materials, and the fruit quality and tree traits that were important to them. Additionally, we asked producers how they define a "good" and/or "bad" level of those traits and if the importance of traits differed according to the major use/markets. Other questions addressed the factors influencing their decision to adopt a new cultivar and the barriers to adopting new cultivars.

Audience survey. From the presurvey interviews, we identified the nine fruit quality and tree traits most frequently mentioned by producers. This list of nine traits was included in the final audience survey along with a tenth option called "other" that allowed respondents to add any other trait(s) deemed important to them. The list of traits in the audience survey included crispness, juiciness, firmness, flavor, sweetness/SSC, sugar/acid balance, shelf life at retail, freedom from storage disorders, plant disease resistance, and other fruit and tree traits.

Audience surveys were conducted at five producer association meetings across the United States: the 2012 Empire State Fruit and Vegetable Expo in New York (98 participants), the 2012 Southeast Apple Producer Meeting in North Carolina (92), the 2011 Washington State Horticultural Association Annual Meeting (90), the 2011 Great Lakes Expo in Michigan (78), and the 2012 Minnesota Apple Growers Association Annual Conference (72). A total of 430 apple producers participated in these audience surveys of which 34 responses were incomplete and unusable (21 from North Carolina, seven from New York, six from Minnesota, and one from Washington). As a result, a total of 396 responses were used in the analysis. We chose these locations because their regional industries provided diversity in geography, production volumes, size of operations, and marketing channels.

A RosBREED project breeder in each state introduced the survey, explaining RosBREED's focus on increasing the efficiency of developing new cultivars using marker-assisted breeding. The scientist described the potential benefits of using marker-assisted breeding, provided updates on their local current breeding programs, and explained the fruit quality/tree traits to be presented in the audience survey. A different scientist presented in each survey location. (We acknowledge potential interviewer effects when conducting the survey. In the analysis we control for the effect of different states and thus different audiences. However, it is not possible for us to separate the effect of the interviewer from the effect of states. The ideal scenario would have been to have the same person conducting the survey in all places; however, this was not logistically possible.)

To capture audience responses to survey questions, the Turning Point™ (Youngstown, OH) polling software was used. This audience survey system provides instant feedback by displaying summary results for each question to the audience as soon as the polling is complete. Each respondent submits responses using an individual Response Card keypad, hereafter referred to as a clicker.

Questions in the audience survey followed a multiple-choice format in which a question was posed and 10 answer categories were given. Each answer was assigned a number. Participants would respond to the question presented by pressing in the clicker the number that corresponds to the response option that best matched their preferences. The system allowed participants to choose only one of the options presented.

After introductory slides, the presenter showed two slides with practice questions to familiarize participants with the Turning Point™ system. The poll for a question was left open until most (more than 90% of the audience) respondents submitted their answers. When the poll was closed to further responses, the system displayed a graphic distribution of the number of responses for each of the multiple choices. When the survey was ended, the system exported the responses to a spreadsheet with each individual clicker identified by a unique code. This enabled tracking of all responses generated from the same clicker.

After the practice questions, the presenter announced the main survey questions. The first question asked participants to choose the trait they considered to be the most important for a successful new apple cultivar from the list of possible responses. In the next slide, the same list of traits was presented and participants were asked to choose the second most important trait. In subsequent slides, the same general procedure was repeated, asking for the least important trait and the second least important trait. The remainder of the survey asked respondents to select, within indicated ranges, the total acres of apple orchards they owned/managed, the number of years they had been involved in the decision-making process for the orchard, their 2010 gross farm income, and the role of the respondent in the apple orchard. Participants were not asked to rank all 10 traits simultaneously. The format described was used to reduce the respondent's fatigue, engage the audience, and stay within the time restrictions of the meeting.

Econometric model. An ordered probit model was used to analyze producers' preferences for apple fruit quality and tree traits. This model was chosen because the response variable created for importance of traits (the dependent variable) was discrete and ordinal (Greene and Hensher, 2008). Based on the questions identifying the top two and the bottom two fruit quality and tree traits

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important in cultivar selection, each trait was assigned a value for each respondent. The most important trait for each respondent was assigned a value of five, the second most important trait was assigned a value of four, the second least important trait was assigned a value of two, and the least important trait was assigned a value of one. The traits that were not considered in any of the categories mentioned (i.e., not identified by the producer as one of the two most important or two least important traits) were considered as the middle choice and assigned a value of three. This method has been used in previous research to elicit level of importance for product attributes (Davis and Gillespie, 2004; Greene and Hensher, 2008).

A producer's ranking is assumed to depend on an underlying utility/satisfaction or measurement of preference derived from the fruit quality and tree traits. The producer knows what informs his or her underlying utility/satisfaction but the researcher does not. The producer ranks the quality traits based on a perception of which of these traits would provide him or her with the most benefits. Here, the benefits are the present value of all the elements that producers consider when ranking the quality traits according to their preferences, which is the same role represented in the utility. This approach is similar to Lancaster's theory of consumer behavior, which states that utility is not derived from a good but rather from the attribute composition of that good (Lancaster, 1966). In this instance, suppose U_{ij} is the utility that producer i derives from trait j and U_{ij} can be expressed as follows:

$$
\begin{aligned}
U_{ij} = {} & \alpha_0 + \alpha_1 Crispness_i + \alpha_2 Juiciness_i \\
& + \alpha_3 Firmness_i + \alpha_4 Flavor_i \\
& + \alpha_5 Soluble\ solids_i + \alpha_6 Sugaracid_i \\
& + \alpha_7 Shelflife_i + \alpha_8 Storage_i \\
& + \alpha_9 Disease_i + \alpha_{10} Other_i + \beta_{1k} State_k \\
& \times Crispness_i + \beta_{2k} State_k \times Juiciness_i \\
& + \beta_{3k} State_k \times Firmness_i + \beta_{4k} State_k \\
& \times Flavor_i + \beta_{5k} State_k \\
& \times Soluble\ solids_i + \beta_{6k} State_k \\
& \times Sugaracid_i + \beta_{7k} State_k \times Shelflife_i \\
& + \beta_{8k} State_k \times Storage_i + \beta_{9k} State_k \\
& \times Disease_i + \beta_{10k} State_k \times Other_i \\
& + \beta_{11} Years \times Crispness_i + \beta_{12} Years \\
& \times Juiciness_i + \beta_{13} Years \times Firmness_i \\
& + \beta_{14} Years \times Flavor_i + \beta_{15} Years \\
& \times Soluble\ solids_i + \beta_{16} Years \\
& \times Sugaracid_i + \beta_{17} Years \times Shelflife_i \\
& + \beta_{18} Years \times Storage_i + \beta_{19} Years \\
& \times Disease_i + \beta_{20} Years \times Other_i \\
& + \varepsilon_{ij}; i = 1, \ldots, 396(n) (1)
\end{aligned}
$$

where α_j is the producer's marginal utility from growing an apple with the traits j (j = crispness, juiciness, firmness, flavor, SSC, sugar/acid balance, shelf life at retail, freedom from storage disorders, disease resistance, and other fruit or tree trait); β_{1k-10k} are the coefficients associated with the interaction effects between the state k where the producer was queried (k = Minnesota, Michigan, Washington, North Carolina, and New York) and the rankings of importance for each apple trait; β_{11-20} are the coefficients associated with the interaction effects between apple producers' years of experience in the decision-making process of managing apple orchards (hereafter years of experience) and the rankings of importance for each apple trait, and ε_{ij} is the residual error term that is not captured by the explanatory variables, which is assumed to follow a normal distribution with mean zero and SD σ_ε. The model coefficients were estimated using STATA™ (College Station, TX).

When estimating the model coefficients, variables were standardized at the means. Also, the trait disease resistance was selected to serve as the base variable for interpretation. This means that the statistical significance of the traits should be interpreted as relative to the base variable. Traits with significant positive coefficients were more likely to be chosen and traits with significant negative coefficients were less likely to be chosen as the most important compared with disease resistance. However, traits determined to be not statistically significant (that is, not significantly different from the base trait, disease resistance) may still be considered of some importance to producers.

The interaction effects between apple traits and the state where the producer was queried were estimated by multiplying the indicator variable for each trait by the indicator variable for each state. In this analysis, Washington was chosen as the base location. Coefficients for these interactions should be interpreted as the difference in the importance assigned by producers in each state relative to Washington producers. To investigate the association of years of experience with responses obtained, we multiplied the variable years of experience with each fruit and tree traits indicator variable. These coefficients should be interpreted as the difference in importance assigned by producers according to the number of years they are involved in the decision-making of managing an apple orchard.

To predict the probability that a trait would be ranked in each ranking category (i.e., most important, second most important, neutral, second least important, and least important), we estimated the marginal effects. Marginal effects were estimated using standardized coefficients. For this estimation, the variable disease resistance was used as the base of comparison. Also, marginal values of the interaction effects (ranking of importance for each trait × state, ranking of importance for each trait × years of experience) were calculated and only those statistically significant different from zero were considered. [For example, if the interaction effect crispness × years of experience was statistically significant, then the marginal effect for crispness = marginal effect for crispness + (marginal effect of the interaction crispness × years of experience) × (average years of experience).]

The previous estimations provide information on the relative importance of apple quality and tree traits with respect to disease resistance. To determine if there were any statistically significant differences in the importance assigned to each trait, we conducted pairwise t tests between the coefficients of the fruit/tree traits included in the ordered probit model.

Results and Discussion

The surveyed Washington producers owned or managed the largest orchards among all surveyed states, averaging 183 ha, followed by New York (91 ha), North Carolina (69 ha), Michigan (50 ha), and Minnesota (23 ha) producers (Table 1). North Carolina producers had the highest average years of experience in the decision-making process (18 years) followed by Michigan (17 years), New York (16 years), Washington (15 years), and Minnesota (13 years) producers. Washington producers had the highest average 2010 gross farm income at \$1.7 million followed by New York with just over \$1.0 million, Michigan at \$560,000, North Carolina at \$483,000, and Minnesota at \$346,000. Nearly 70% of participants were orchard owners, followed by 28% managers, and 3% lessees (Table 1).

Only statistically significant coefficients are reported in Table 2. Compared with disease resistance, apple producers ranked fruit flavor as the most important quality trait with a coefficient of 1.92. This indicates that respondents placed a higher importance on flavor when compared with disease resistance when thinking of quality traits that would make a successful apple cultivar. The second most important fruit trait was crispness (1.35) followed by firmness (0.67). Firmness is associated with crispness and evaluated by the resistance of the fruit flesh when chewed with the molars, whereas crispness is described as the cracking noise when fruit is bitten with the front teeth (Evans et al., 2012). This finding is consonant with findings from consumer studies indicating that relatively high levels of firmness and crispness are preferred to lower levels (Daillant-Spinnler et al., 1996; Jesionkowska et al., 2006; McCluskey et al., 2007, 2013). Producers also ranked shelf life at retail and fruit juiciness of greater importance than disease resistance. Maintaining and delivering apples with ideal levels of flavor, crispness, firmness, shelf life at retail, and juiciness are believed to improve consumer acceptability and retail inventory value. The "other" category was also statistically significant ranked as more important than disease resistance. Responses in this open-ended category included ease of management, productivity, overall fruit texture, fruit appearance, and fruit size. The fruit quality trait coefficients for sugar/acid balance, freedom from storage disorders, and sweetness/soluble solids were not statistically significant different from zero,

Table 1. Summary statistics for variables used in ordered probit model for fresh apple producer audience survey participants at five apple producer meetings in 2011–12 (n = 396).

Variable	Description	Mean	SD
Acres-Michigan	Average total orchard acres owned/managed by Michigan producers	123.56	180.12
Acres-Minnesota	Average total orchard acres owned/managed by Minnesota producers	50.75	89.06
Acres-New York	Average total orchard acres owned/managed by New York producers	224.26	226.20
Acres-North Carolina	Average total orchard acres owned/managed by North Carolina producers	170.34	365.20
Acres-Washington	Average total orchard acres owned/managed by Washington producers	451.96	518.80
Years-Michigan	Michigan participant's average years of decisions making experience	16.64	9.07
Years-Minnesota	Minnesota participant's average years of decisions making experience	13.44	9.44
Years-New York	New York participant's average years of decisions making experience	16.45	9.43
Years-North Carolina	North Carolina participant's average years of decisions making experience	18.36	8.68
Years-Washington	Washington participant's average years of decisions making experience	15.07	9.82
Income-Michigan	Average 2010 gross farm income ($1000) in Michigan	560.27	836.28
Income-Minnesota	Average 2010 gross farm income ($1000) in Minnesota	345.79	798.10
Income-New York	Average 2010 gross farm income ($1000) in New York	1047.27	1125.24
Income-North Carolina	Average 2010 gross farm income ($1000) in North Carolina	482.72	959.43
Income-Washington	Average 2010 gross farm income ($1000) in Washington	1708.82	1400.32
Role	Role of participant (% of all respondents)	1.58	0.89
	1 = Owner (69.70%)		
	2 = Lessee (2.70%)		
	3 = Manager (27.60%)		
Region	Geographical location of orchard (% of all respondents)	3.03	1.39
	1 = Michigan (19.75%)		
	2 = Minnesota (16.71%)		
	3 = New York (23.04%)		
	4 = North Carolina (17.97%)		
	5 = Washington (22.53%)		

Table 2. Estimated ordered probit model coefficients for fresh apple traits based on audience survey data collected at five apple producer meetings in 2011–12 (n = 396).

Variable	Coefficient[z]	SE
Fruit flavor	1.92***	0.19
Fruit crispness	1.35***	0.22
Fruit firmness	0.67***	0.22
Other fruit or plant trait	0.59***	0.19
Shelf life at retail	0.57***	0.20
Fruit juiciness	0.32*	0.19
Sugar/acid balance	0.22	0.19
Sweetness/soluble solids content (°Brix)	0.21	0.19
Freedom from storage disorders	0.19	0.19
Disease resistance	Base	
Michigan × disease resistance[y]	0.17***	0.03
Michigan × shelf life at retail[y]	–0.10***	0.02
Michigan × fruit juiciness[y]	–0.07***	0.02
Minnesota × disease resistance[y]	0.16***	0.03
Minnesota × sugar/acid balance[y]	0.06***	0.02
Minnesota × fruit crispness[y]	0.03*	0.02
Minnesota × freedom from storage disorders[x]	–0.10***	0.02
Minnesota × shelf life at retail[y]	–0.09***	0.02
Minnesota × fruit firmness[y]	–0.07***	0.02
New York × disease resistance[y]	0.11***	0.03
New York × other fruit or tree trait[y]	–0.11***	0.02
North Carolina × disease resistance[y]	0.20***	0.03
North Carolina × freedom from storage disorders[x]	–0.10***	0.02
North Carolina × sugar/acid balance[x]	–0.05**	0.02
Years × fruit crispness[x]	0.07*	0.04
Years × fruit firmness[x]	0.08**	0.04
Years × disease resistance[x]	–0.25***	0.04
Cutoff value 1[w]	–0.99	0.16
Cutoff value 2[w]	–0.51	0.16
Cutoff value 3[w]	1.75	0.15
Cutoff value 4[w]	2.31	0.17
Number of observations	3280.00	
Log likelihood	–3255.26	
Pseudo R^2	0.14	

[z]*, **, *** Significant at $P \leq 0.10$, 0.05, or 0.01, respectively.
[y]Interaction between fruit trait and the production state of the respondent.
[x]Interaction between fruit trait and years of decision-making experience of the respondent.
[w]Cutoff value for the ordered probit model.

indicating that these traits were not statistically different in importance than the base trait, disease resistance.

Only statistically significant interactions effects were reported in Table 2. Compared with Washington producers, disease resistance was more important for producers in all other states (North Carolina, Michigan, Minnesota, and New York). This is not surprising, because Washington producers have a drier climate that is less favorable for development of bacterial and fungal diseases than the other regions. Shelf life at retail was less important for Minnesota and Michigan than for Washington producers. This result could reflect the fact that 60% of apples grown in Michigan are for the processing market; thus, shelf life at retail was not deemed as important as for Washington producers (Michigan Apple Committee, 2013). Freedom from storage disorders was less important for North Carolina and Minnesota than for Washington producers. These results may have derived from the smaller fruit volumes produced in Minnesota and North Carolina and the relatively greater proportion of fruit marketed directly to consumers in those states. In contrast, producers in Washington expect to store a large portion of their production in storage facilities, because they market fruit over a 12-month period. Sugar/acid balance was more important for Minnesota and less important for North Carolina than for Washington producers. Fruit crispness was ranked more important in Minnesota compared with Washington, perhaps because the very crisp cultivar Honeycrisp was developed and initially commercialized in that area. However, fruit firmness was less important for Minnesota compared with Washington producers. Fruit juiciness was less important for Michigan than for Washington producers. The "other fruit and tree trait" category was less important for New York compared with Washington producers. This category was selected by nine producers in Washington and by four producers in New York and included ease of management, productivity, overall fruit texture, fruit appearance, and fruit size.

Table 3. Marginal effect of relative importance of apple traits based on audience survey data collected at five apple producer meetings in 2011–12 (n = 396).

	Least important trait (ranking = 1) dy/dx	Second least important trait (ranking = 2) dy/dx	Not selected (ranking = 3) dy/dx	Second most important trait (ranking = 4) dy/dx	Most important trait (ranking = 5) dy/dx
Fruit flavor[z]	–0.080***[y]	–0.097***	–0.452***	0.148***	0.481***
Fruit crispness	–0.225***	–0.223***	–0.254***	0.303***	0.415***
Fruit firmness	–0.224***	–0.085***	–0.073	0.115	0.123** [y]
Other fruit or plant trait	–0.046***	–0.052***	–0.058	0.069***	0.080**
Shelf life at retail	–0.045***	–0.050***	–0.054	0.069***	0.076**
Fruit juiciness	–0.029**	–0.030* [y]	–0.016	0.039	0.037
Sugar/acid balance	–0.021	–0.022	–0.007	0.026	0.024
Sweetness/soluble solids content (°Brix)	–0.020	–0.020	–0.006	0.025	0.022
Freedom from storage disorders	–0.020	–0.019	–0.005	0.022	0.020
Disease resistance	Base	Base	Base	Base	Base
Michigan producers					
Shelf life at retail	–0.033***	–0.039***	–0.055	0.059***	0.068***
Fruit juiciness	–0.021***	–0.023***	–0.017	0.031***	0.031***
Disease resistance	–0.019***	–0.017***	0.002	0.019***	0.016***
Minnesota producers					
Fruit crispness	–0.101*	–0.115*	–0.270	0.179*	0.306*
Fruit firmness	–0.072***	–0.078***	–0.074	0.107***	0.117***
Shelf life at retail	–0.034***	–0.040***	–0.055	0.060***	0.069***
Sugar/acid balance	–0.027***	–0.028***	–0.006	0.032***	0.029***
Disease resistance	–0.018***	–0.017***	0.001	0.018***	0.015***
Freedom from storage disorders	–0.008***	–0.009***	–0.004	0.011***	0.011***
New York producers					
Other fruit or tree trait	–0.033***	–0.040***	–0.059	0.058***	0.071***
Disease resistance	–0.013***	–0.012***	0.001	0.013***	0.011***
North Carolina producers[x]					
Sugar/acid balance	–0.016**	–0.017**	–0.007	0.021**	0.020**
Disease resistance	–0.023***	–0.021***	0.002	0.023***	0.019***
Freedom from storage disorders	0.004***	–0.009***	–0.006	0.011***	0.011***

[z]Marginal effects were calculated considering significant interactions with demographic variables. For example, marginal effect for fruit crispness = marginal effect for fruit crispness + (marginal effect of interaction years of experience * fruit crispness) * (average number of years of experience).

[y]*, **, *** Significant at $P \leq 0.10$, 0.05, or 0.01, respectively.

[x]Marginal effects for each state were calculated considering significant interactions with state variables. For example, marginal effect for fruit sugar/acid balance North Carolina producers = marginal effect for fruit sugar/acid balance + (marginal effect of interaction fruit sugar/acid balance * North Carolina).

Table 4. Pairwise *t* test comparison of selected fruit and plant quality trait coefficients, based on audience survey data collected at five apple producer meetings in 2011–12.

	Fruit crispness	Fruit juiciness	Fruit firmness	Fruit flavor	Sweetness/soluble solids content (°Brix)	Sugar/acid balance	Shelf life at retail	Freedom from storage disorders	Other fruit or tree trait
Fruit crispness	—	—	—	—	—	—	—	—	—
Fruit juiciness	1.03***	—	—	—	—	—	—	—	—
Fruit firmness	0.68***	–0.35**	—	—	—	—	—	—	—
Fruit flavor	–0.57***	–1.60***	–1.25***	—	—	—	—	—	—
Sweetness/soluble solids (Brix)	1.14***	0.11	0.46***	1.71***	—	—	—	—	—
Sugar/acid balance	1.13***	0.10	0.45**	1.70***	–0.01	—	—	—	—
Shelf life at retail	0.79***	–0.25**	0.11	1.36***	–0.36***	–0.35**	—	—	—
Freedom from storage disorders	1.16***	0.13	0.48***	1.73***	0.02	0.03	0.38***	—	—
Other fruit or tree trait	0.76***	–0.27**	0.08	1.33***	–0.38***	–0.37***	–0.02	–0.40***	—

[z]*, **, *** Significant at $P \leq 0.10$, 0.05, or 0.01, respectively.

Producers with more years of experience in orchard decision-making ranked crispness and firmness as more important, and disease resistance as less important, than producers with fewer years of experience. Producers with more years of experience might have more exposure and knowledge of diseases and treatment options.

In relation to the marginal effects estimates (Table 3), fruit flavor had a significantly higher probability of being chosen as the most important trait compared with disease resistance. Fruit crispness was next followed by fruit firmness, other fruit or plant trait provided by the producer, and shelf life at retail. Fruit juiciness, sugar/acid balance, sweetness/SSC, and freedom from storage disorders were not statistically significant different from disease resistance.

When estimating marginal effects by state, in Michigan, shelf life at retail and fruit juiciness had a lower probability of being selected as the most important fruit trait compared with the rest of the states, whereas disease resistance had a higher probability. Minnesota growers assigned sugar/acid balance and disease resistance a higher probability of being selected as the most important fruit and tree trait compared with the rest of the states. This same group of growers assigned a lower probability to fruit firmness, shelf life at retail, and freedom from storage disorders. The probability that Minnesota growers chose fruit crispness as the most important fruit trait is positive and statistically significant; however, it is lower compared with the rest of the states. For New York producers, the probability that other fruit and tree trait (provided by the producer) were selected as the most important trait was lower compared with respondents in other states. For the same group of producers, the probability that disease resistance was selected as the most important trait was higher compared with the other states. In North Carolina, the probability of selecting sugar/acid balance and freedom from storage disorders as the most important traits was lower and disease resistance was higher compared with the other states.

Results from the pairwise *t* test comparisons were consonant with previous results (Table 4). A positive coefficient indicated that trait in the first row was ranked higher than trait in the first column. A negative coefficient indicates otherwise; trait in the first row was ranked lower than trait in the first column. For example, fruit flavor and crispness were ranked significantly higher than all other traits listed in terms of their importance in a successful apple cultivar. However, no statistically significant differences were found among fruit firmness, shelf life at retail, and other fruit and tree traits. Similar to the previous analyses, we found no significant differences among juiciness, sweetness/soluble solids, sugar/acid balance, and freedom from storage disorders.

Audience survey methodology. Audience response survey technologies have been used widely in academic settings to educate and obtain group feedback (Hall et al., 2005). Additionally, the method has potential to be used in research settings (McCarter and Caza, 2009). Hall et al. (2005) claimed that use of audience survey technology increases audience engagement in a group setting. Powe et al. (2009) indicated that audience survey technology provides several benefits including the ability to survey larger groups, elimination of data entry errors, ease of use, and decreased time when compared with pen and paper survey methods. McCarter and Caza (2009) considered the audience survey technology as a reliable method of data collection. However, one concern related to using this technology to conduct research is that the participants are able to view the results of the audience as a whole on completion of each question. By displaying the graphic distribution of the number of responses for each question, the audience survey format allows for the group's overall response to potentially influence each individual respondent. This effect is somewhat similar to quantifying the responses of focus groups. We argue that understanding producers' rankings of fruit quality and plant traits in a group setting is valuable because producers are exposed to and influenced by external information that, in many cases, comes from their producer cohort. Typically, decisions are made within a context with several sources of information rather than in isolation. Thus, we claim that any potential group influence, rather than causing a biasing artifact, strengthens the audience survey methodology.

Conclusions

Determining which fruit quality and tree traits to prioritize when breeding a new apple cultivar is a complex problem. One solution is to systematically obtain input from the supply chain. In this study, we collected apple producers' rankings of importance for fruit quality and tree traits using an audience survey, a survey mechanism that provided immediate feedback to the audience. To our knowledge, this is the first reported attempt to systematically obtain and analyze information collected from agricultural producers through real-time audience surveys. To our knowledge, no previous study had formally surveyed producers to elicit their preferences for fruit quality and tree traits. An ordered probit model was used to determine the traits that participating producers considered important for a successful new apple cultivar. Results implied that producers consider fruit quality traits such as flavor, crispness, and firmness as more important relative to the horticultural trait of disease resistance. These fruit quality traits are also more relevant to consumers than is disease resistance. This suggests that U.S. apple producers may apply the concepts of marketing-oriented horticulture, assigning greater importance to consumer-related fruit quality traits rather than horticultural traits. Producers' rankings of the apple traits varied across states, likely as a result of contrasting climatic conditions, historical availability of cultivars, and market settings. Years of experience also affected apple producers' rankings of trait importance with certain fruit quality traits more likely to outrank plant traits for more experienced producers, perhaps because experience leads to greater understanding of the impact of marketing on production.

An important objective of the RosBREED project is to obtain information on the value that members of the apple supply chain assign to different fruit quality and tree traits and incorporate this information into apple breeding decisions to decrease risks in developing and commercializing new apple scion cultivars. This specific study focused on the producer component of the supply chain. This approach may facilitate more rapid and targeted availability of new high-quality apples with desired traits, which will ultimately increase the consumption of apples and other fruit products. Furthermore, our results can be used by breeding programs and associated scientific disciplines in future studies to strategically impact future industry growth and profitability through the coordination of supply chain member needs.

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