Result of a Survey on Grape Breeder's Perceived Priorities in Grape Genetics Research

Jayson L. Lusk and Scott Davidson*

October 11, 2012

*Authors are professor and Willard Sparks Endowed Chair in the Department of Agricultural Economics at Oklahoma State University and professor and Chair of the Philosophy Department at Oklahoma City University.

The research was funded by a Specialty Crop Research Initiative Competitive Grant, Award No. 2011-51181-30635, of the USDA National Institute of Food and Agriculture and was conducted as part of the VitisGen project

Executive Summary

- The purpose of this study was to identify grape researcher perceptions (including geneticists and plant breeders) of the priorities that should guide current and future grape research initiatives.
- An international survey was administered to 718 individuals thought to be involved in grape genetics and breeding research, and 140 responded to at least a portion of the survey.
- Out of 12 traits related to scion cultivar improvement, respondents believed that Powdery mildew resistance, Downy mildew resistance, and Drought/heat tolerance would be most economically beneficial, if commercialized. Traits related to abiotic stress were perceived to be more economically beneficial than traits related to biotic stress, fruit quality, or viticultural traits.
    - However, there was geographic variation in anticipated economic benefits of resistance to abiotic stress. Respondents from New York more highly valued downy mildew resistance and mid-winter hardiness than respondents from California. California respondents, by contrast, regarded the economic benefits of powdery mildew resistance to be 8.8 times higher than downy mildew resistance, but it was only 3.4 times higher for New York respondents, and only 1.1 times higher for respondents from other locations.
- Out of 12 traits related to scion cultivar improvement, respondents believed Powdery mildew resistance, Downy mildew resistance, a 5% improvement in yield, and early ripening could be most rapidly developed.
- Fifty three percent of respondents said they currently use marker-assisted technology in their research. Among users of marker-assisted technology, on average they said that 53.4% of seedlings are currently screened using markers. Markers were primarily used for efficiency and to confirm identity or relatedness. Reasons for non-use of marker-assisted technology were diverse but were not generally related to lack of understanding of the technology.
- Researchers identified lack of funding as the primary difficulty in *implementing* breeding priorities followed by a lack of support staff. Lack of funding, lack of genetic information, and lack of agreement about trait priorities across interested parties were identified as the main difficulties in *setting* breeding priorities.
- Combining the perceptions of economic benefit and time of implementation in an economic priority index, it is clear from the survey results that resistance to powdery mildew is perceived to be the top priority, and if combined with resistance to downy mildew, an overwhelming priority in comparison to the other ten priorities studied.

Background on Survey and Characteristics of Respondents

This survey represents the initial attempt to collect data that will enter into the economic-impact models as well as to provide input to those who set grape breeding priorities. This survey mainly focused on grape researchers and breeders. Future efforts will focus on grape growers and consumers.

In late August and early September 2012, an internet survey was administered to individuals involved in the following groups: i) members of the Grape Research Community (first organized by the International Grape Genome Program, which includes breeders, geneticists, viticulturists, nurserymen, industry leaders, enologists, physiologists and related scientists), ii) attendees of the 10th international Conference on Grapevine Breeding and Genetics held in August 2010, and iii) members of the Grape Crop Germplasm Committee. After deleting duplicate names in the three lists, 718 email addresses remained, and the survey was sent to each of these individuals. Ultimately, 140 individuals responded to at least a portion of the survey.

Before proceeding to the primary results, we first reveal the characteristics of the respondents to provide context for the results that follow.

The majority of respondents (62%) worked for a University and 24% worked for the federal government. The remaining respondents worked for a private company (6%), were independent grape producers (6%), or worked for another entity (4%).

Only 19% of respondents were members of the VitiGen project. Of those who were a part of the project, 42% were members of the breeding team, 42% were members of the phenotyping team, 29% were members of the genotyping team, 13% were members of the extension and outreach team, and 4% were members of the economics team.

Respondents were involved in all facets of the grape industry, but mainly focused on wine and scion breeding. When asked which area of the grape industry the respondent primarily worked, the following information was obtained (note: respondents could check all categories that applied to their situation).

Answer	%
Wine	45%
Scion breeding	36%
Table grapes	35%
Other	26%
Rootstock breeding	18%
Juice	9%
Raisins	6%

Respondents represented a wide diversity of geographic regions with over 28 different countries being represented. The largest fraction of respondents was from the U.S. (40.5%) followed by Italy (8.7%), Australia (5.8%), France and Chile (each comprising 4.3% of the sample), and Canada and South Africa (each comprising 3.6% of the sample). Among the U.S. respondents, 43% were from New York, 21% were from California, 7% were from Missouri, and the remaining respondents were from one of 16 other states.

Seventy eight percent of respondents said that they were directly involved in research related to grape breeding or genetics. Of those involved in grape breeding and genetics, 57% said they worked on issues related to biotic stress, 57% said they worked on issues related to fruit quality, 45% worked on viticultural traits, 34% worked on issues related to abiotic stress, and 5% worked on other issues (note: respondents could check all categories that applied to their situation).

Perceived Economic Benefit and Speed of Development for 12 Traits

Respondents were queried on the perceived economic benefit (and speed of development) of 12 traits of interest to the grape industry. In consultation with various members of the VitisGen team, we compiled a list of four key attributes or categories representing goals for research (fruit quality, abiotic stress, biotic stress, and viticultural traits) and for each category, we considered three traits. Thus, a total of 4x3=12 traits were evaluated.

A. Fruit quality
1. Improved cluster architecture
2. Improved balance of sugar/pH/acidity
3. Reduction in off-aroma compounds

B. Abiotic stress
4. Mid-winter hardiness
5. Drought/heat tolerance
6. Chilling fulfillment for uniform bud break

C. Biotic stress
7. Powdery mildew resistance
8. Downy mildew resistance
9. Pierce's disease resistance

D. Viticultural traits
10. 5% improvement in yield
11. Early ripening
12. Improved vine architecture for mechanization

For each of these traits, we were interested in determining respondents' perceptions of i) the relative economic benefit of commercializing each trait and ii) the relative speed with which the traits could be developed.

Discussion of Best-Worst Method

The approach used to elicit this information is a relatively new technique called "best worst" scaling. The best-worst method works as follows. Respondent are shown a set of items (in this case a set of possible traits of interest in grape breeding) and are asked to indicate which is best (or in our case, most economically beneficial) and which is worst (or least economically beneficial). Respondents make several repeated choices where the set of traits varies across questions. Responses to the questions can be used to measure each item's position on a scale or continuum of the construct of interest (in this case it is economic benefit or speed of development).

Figure 1 below shows a screen-shot of one of the best-worst questions used in this study to measure perceived economic impact.

Best-worst scaling has several advantages over other methods of measurement. A major difficulty with rating-based methods (e.g., where a person responds on a scale of 1 to 5 with 1 being not important and 5 being very important) is that people are not forced to make trade-offs between the relative importance of issues. Indeed, it is common for people to say all issues are "important." Another problem with rating-based methods is that different people use the scale differently, with a 5 for one person possibly representing a 4 for another. This is a particular problem for multicultural surveys such as this one. Additionally, the aforementioned rating scales provide measurement on an ordinal scale. Best-worst scaling avoids these pitfalls. By having people choose the best and worst options, people are forced to decide which issues are more or less important, and unlike rating scales, there is only one way for people to respond to the question (with a choice). Moreover, best-worst scaling provides a measurement of the underlying construct on a ratio scale, such that we can say for example that commercializing trait A is X times more economically beneficial than commercializing trait B.

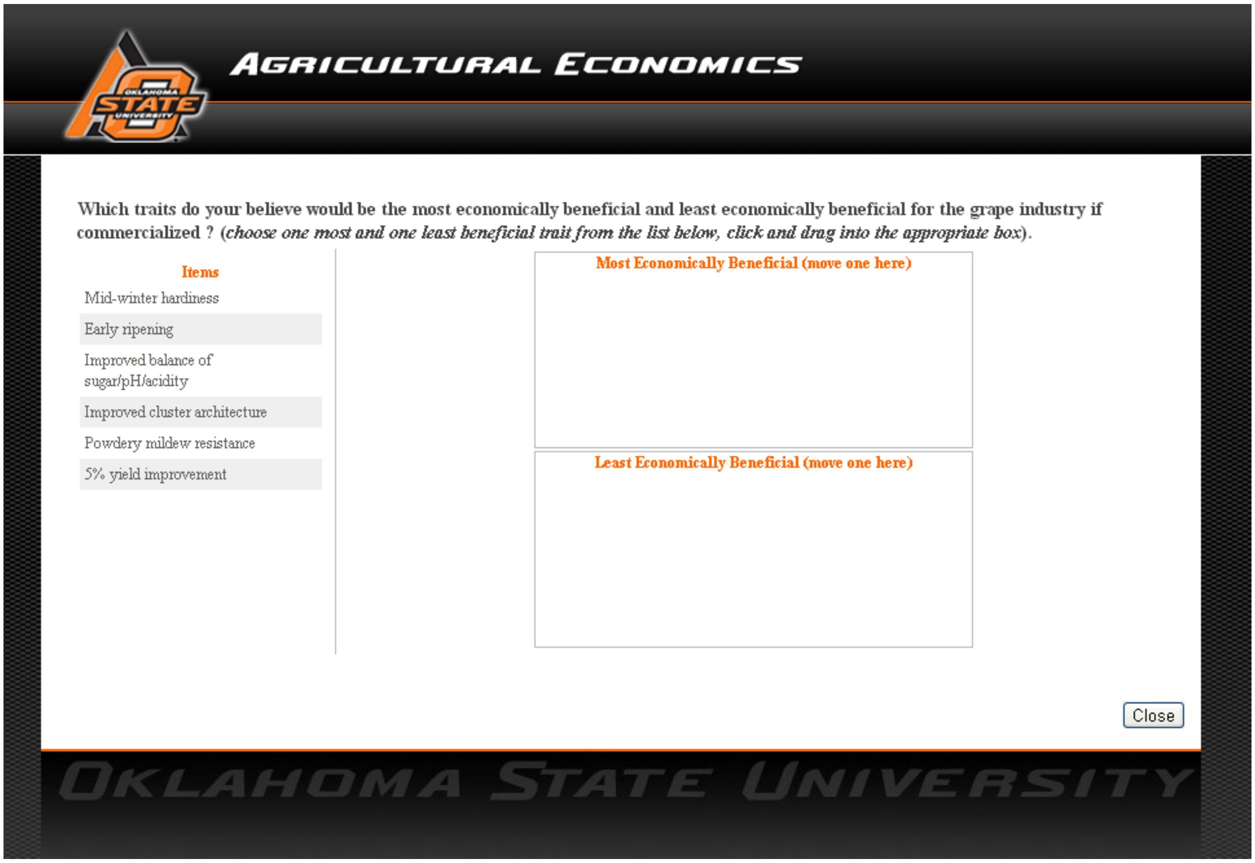

Figure 1. Screen shot of best-worst question measuring relative economic benefit of 12 traits

Prior to answering the questions like the one shown in figure 1 above, respondents were told:

> "Each question lists six different traits that are the focus of genetics research for scion cultivar improvement (generally across all types of grapes including table grapes, wine, etc.).
>
> In each question, we would like you to indicate which one trait you believe would be most economically beneficial for the industry if commercialized and which one item you believe would be least economically beneficial for the industry if commercialized."

In the first set of questions, respondents were asked to answer 8 questions like the one in figure 1, each of which listed six traits (drawn from the full list of 12), from which the respondent indicated the one perceived as most economically beneficial and the one perceived as least economically beneficial. In the second set of questions, respondents again answered 8 questions, each of which listed six traits (drawn from the list of 12) and indicated the one perceived as being most rapid to develop and the one being perceived as least rapid to develop (see figure 2).

For each best-worst question, the data are modeled assuming respondents choose the two options in each question that maximize the difference on the underlying scale of interest. Resulting coefficients from the multinomial logit choice models are converted to probabilities to place items on ratio scales of economic benefit and speed of development.

Each question entailed subjects picking one issue as “best” and “worst” out of a list of six. The six issues were drawn from the full set of 12 issues shown previously. Issues were assigned to questions using a near 100% efficient balanced incomplete block design, such that each issue appeared an equal number of times and in near equal frequency with every other issue.

When responding to each best-worst question, respondents can be conceptualized as choosing the two items that maximize the difference between two items on an underlying scale of economic benefit (or speed of development). Each choice set had six items, and as such there are 6(6-1) = 30 possible best-worst combinations a person could choose for each question. The particular pair of items chosen as best and worst, then, represents a choice out of all 30 possible pairs that maximizes the difference in perceived sustainability.

Formally, let λ_j represent the location of trait *j* on the underlying scale of perceived economic benefit (or speed of development) and let the true or latent unobserved level of perceived economic benefit (or speed of development) for individual *i* be given by $I_{ij} = \lambda_j + \varepsilon_{ij}$, where ε_{ij} is a random error term. The probability that the respondent chooses, say, trait *j* and trait *k*, as the most and least economically beneficial, respectively is the probability that the difference in I_{ij} and I_{ik} is greater than all other 29 possible differences in the choice set. If the ε_{ij} are distributed iid type I extreme value and *J* is the total number of issues, then this probability takes the multinomial-logit (MNL) form:

(1) Prob(trait *j* is chosen “best” and trait *k* is chosen “worst”) = $$\frac{e^{\lambda_j - \lambda_k}}{\sum_{l=1}^{J}\sum_{m=1}^{J} e^{\lambda_l - \lambda_m} - J}$$

The parameters λ_j, can be estimated by maximization of the log-likelihood function based on the probability statement in eq. (1). That is, the dependent variable takes the value of 1 for the pair of values chosen by the consumer as most and least sustainable, and a 0 for the reaming 29 pairs of items in the choice set that were not choices as most and least sustainable. The estimated coefficients, λ_j, represents the perceived economic benefit (or speed of development) of issue *j* relative to one action normalized to zero for identification.

To place items on a ratio scale of perceived economic benefit (or speed of development), the forecasted probability that each issue is picked as most economically beneficial (or rapidly developed) is calculated, and is called the “importance score”:

(2) importance score for trait *j* = $$\frac{e^{\hat{\lambda}_j}}{\sum_{k=1}^{J} e^{\hat{\lambda}_l}}.$$

These scores must sum to one across all 12 actions studied. Equation (2) reports the perceived economic benefit (or speed of development) of trait *j* on a ratio scale, meaning that if one issue has a score twice that of another issue, it can accurately be said that the former value is perceived twice as economically beneficial as the latter.

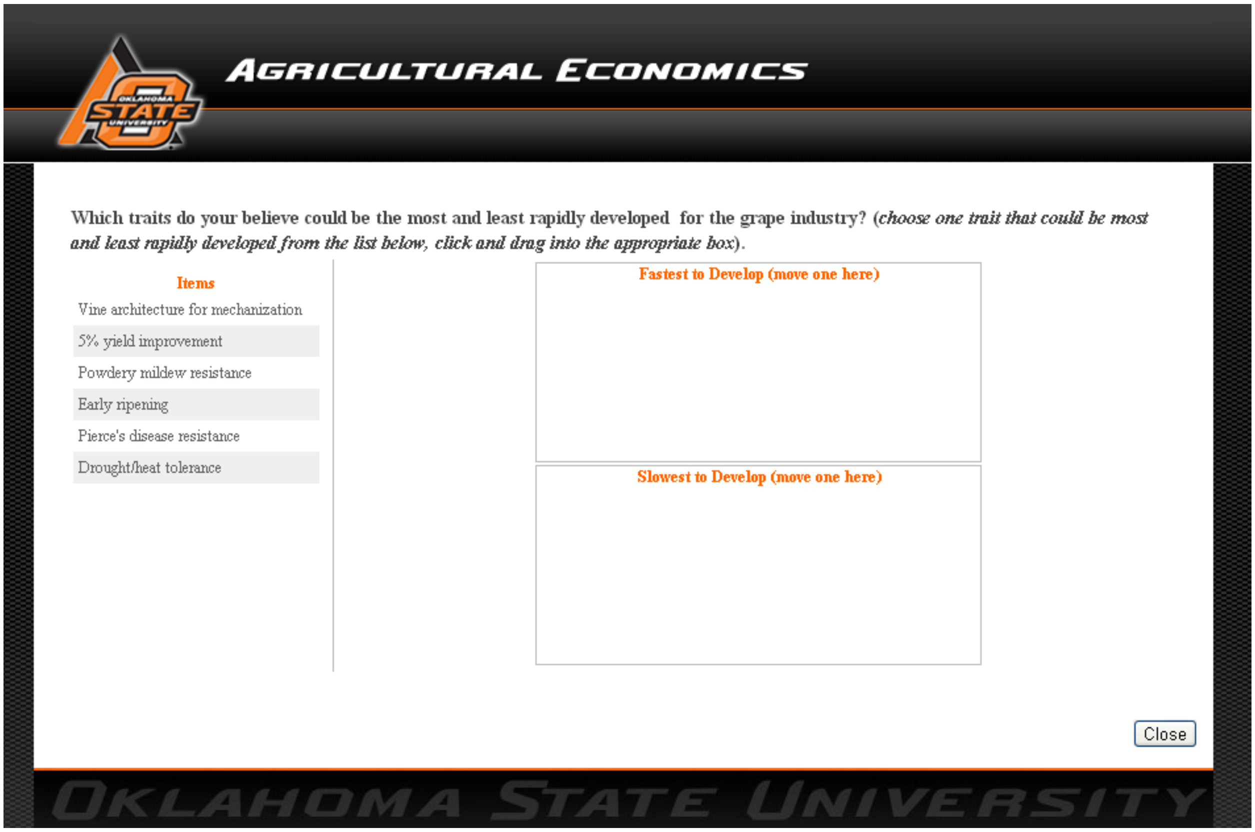

Figure 2. Screen shot of best-worst question measuring relative speed of development of 12 traits[1]

[1] Prior to answering the questions on speed of development, respondents were told: "We are now going to ask you another set of eight repeated questions. Each question lists six different traits that are the focus of genetics research for scion cultivar improvement (generally across all types of grapes including table grapes, wine, etc.). The differences is that now in each question, we would like you to indicate which one trait you believe could be most rapidly developed and which one item you believe would be slowest to develop."

Results on Relative Economic Benefit

Table 1 reports the results of the MNL estimation and the calculated importance scores for the entire sample of respondents. The results are sorted in terms of relative importance. Powdery mildew resistance is deemed the most economically beneficial. In our sample of respondents, the estimates suggest that out of all 12 traits, 25.8% would pick Powdery mildew resistance as most economically beneficial, whereas only 16.6% downy mildew resistance as most economically beneficial. Somewhat surprisingly, only 3.2% would pick a 5% yield improvement as most economically beneficial. On this last point, it must be noted that the results of this survey come primarily from grape breeders and researchers not producers – the latter of which might have different perceptions about relative economic benefits.

Table 1. Perceived Relative Economic Benefit of Commercializing 12 Traits

Trait	**MNL Estimate**	**Economic Benefit Importance Score**
Powdery mildew resistance	1.629* (0.115)	25.8%
Downy mildew resistance	1.187* (0.110)	16.6%
Drought/heat tolerance	1.025* (0.116)	14.1%
Improved balance of sugar/pH/acidity	0.345* (0.117)	7.1%
Early ripening	0.168 (0.115)	6.0%
Pierce's disease resistance	0.096 (0.114)	5.6%
Vine architecture for mechanization	0	5.1%
Reduction in off-aroma compounds	-0.066 (0.116)	4.7%
Mid-winter hardiness	-0.116 (0.114)	4.5%
Improved cluster architecture	-0.278* (0.116)	3.8%
Chilling fulfillment for uniform bud break	-0.331* (0.113)	3.6%
5% improvement in yield	-0.465* (0.111)	3.2%
Number of Choices	1688	
Number of People	134	
Chi-Square Test Statistic for Model Significance	776.46*	

As indicated, the 12 traits each belonged to one of four attributes or categories. To determine the relative importance of each category, the importance scores of each of the categories' traits were simply summed. As shown in table 2, developments on biotic stress were deemed as most economically beneficial – more than twice as beneficial as abiotic stress trait developments.

Table 2. Relative Category Importance (Economic Benefit)

Category and Trait	Economic Importance Score
Biotic Stress	**48.0%**
Powdery mildew resistance (25.8%)	
Downy mildew resistance (16.6%)	
Pierce's disease resistance (5.6%)	
Abiotic Stress	**22.2%**
Drought/heat tolerance (14.1%)	
Mid-winter hardiness (4.5%)	
Chilling fulfillment for uniform bud break (3.6%)	
Fruit Quality	**15.6%**
Improved balance of sugar/pH/acidity (7.1%)	
Reduction in off-aroma compounds (4.7%)	
Improved cluster architecture (3.8%)	
Viticultural Traits	**14.3%**
Early ripening (6%)	
Vine architecture for mechanization (5.1%)	
5% improvement in yield (3.2%)	

The preceding were calculated by aggregating over the entire sample of survey respondents. However, there may be geographic differences in the economic benefits of different traits. As such table 3 reports the results when importance scores are calculated for the two US locations with the most respondents and then for all other locations excluding California and New York.

Table three reveals significant heterogeneity across location. Powdery mildew resistance was perceived as most economically beneficial in all locations, but this belief was most pronounced in California where it was 495/12.2 = 4.13 more important than the next most important issue (drought/heat tolerance). In New York, however, downy mildew resistance as the second most important issue followed by mid-winter hardiness. Neither of these issues was perceived as economically important in California. In all other locations, downy mildew resistance was perceived as almost as important as powdery mildew resistance.

Table 3. Importance Scores on Relative Economic Benefit by Location

Trait	**California**	**New York**	**Other Locations**
Powdery mildew resistance	49.5%	39.7%	20.9%
Drought/heat tolerance	12.2%	6.9%	16.0%
5% improvement in yield	9.5%	5.3%	2.2%
Pierce's disease resistance	9.0%	6.4%	4.6%
Downy mildew resistance	5.6%	11.7%	19.4%
Vine architecture for mechanization	3.2%	4.6%	4.9%
Early ripening	2.9%	4.1%	6.5%
Reduction in off-aroma compounds	1.9%	4.4%	4.8%
Chilling fulfillment for uniform bud break	1.7%	2.8%	3.7%
Improved balance of sugar/pH/acidity	1.7%	4.8%	8.5%
Improved cluster architecture	1.4%	2.3%	4.3%
Mid-winter hardiness	1.3%	7.2%	4.1%
N choices	96	181	728

Results on Speed of Development

Although it might legitimately be asked whether grape researchers have accurate perceptions of the economic benefits of commercializing different traits (as compared, say, to producers), it is almost certainly the case that grape breeders and researchers are relatively well informed and have relatively accurate perceptions about the speed with which different traits can be developed.

Table 4 reports the results related to the perceived speed of developing 12 traits sorted from the fastest to slowest. Not only were powdery and downy mildew perceived as most economically important (see table 1), table 2 shows that respondents believed they are the two traits that can be most rapidly developed. However, the two lists are not identical. For example, whereas a 5% yield improvement was thought to be least economically beneficial (table 1), table 4 shows respondents believe the outcome can be developed relatively rapidly.

Table 4. Perceived Relative Speed of Developing 12 Traits

Issue	**MNL Estimate**	**Speed Importance Score**
Powdery mildew resistance	1.408* (0.122)	20.1%
Downy mildew resistance	1.123* (0.119)	15.1%
5% improvement in yield	0.812* (0.122)	11.1%
Early ripening	0.804* (0.123)	11.0%
Pierce's disease resistance	0.489* (0.122)	8.0%
Improved cluster architecture	0.357* (0.126)	7.0%
Improved balance of sugar/pH/acidity	0.123 (0.124)	5.6%
Mid-winter hardiness	0.071 (0.120)	5.3%
Vine architecture for mechanization	0.0%	4.9%
Reduction in off-aroma compounds	-0.026 (0.122)	4.8%
Chilling fulfillment for uniform bud break	-0.123 (0.121)	4.3%
Drought/heat tolerance	-0.500* (0.118)	3.0%
Number of Choices	853	
Number of People	112	
Chi-Square Test Statistic for Model Significance	481.59*	

Table 5 shows the perceived speed of development aggregated by the four traits of interest. Respondents believed developments in biotic stress can be most rapidly developed.

Table 5. Relative Category Importance (Speed of Development)

Category and Trait	**Speed Importance Score**
Biotic Stress	**43.2%**
Powdery mildew resistance (20.1%)	
Downy mildew resistance (15.1%)	
Pierce's disease resistance (8%)	
Viticultural traits	**27.0%**
5% improvement in yield (11.1%)	
Early ripening (11%)	
Vine architecture for mechanization (4.9%)	
Fruit Quality	**17.4%**
Improved cluster architecture (7%)	
Improved balance of sugar/pH/acidity (5.6%)	
Reduction in off-aroma compounds (4.8%)	
Abiotic Stress	**12.6%**
Mid-winter hardiness (5.3%)	
Chilling fulfillment for uniform bud break (4.3%)	
Drought/heat tolerance (3%)	

Ideally, one would want to take an issue's economic benefit that will occur in all future years and determine the net-present value by discounting how long it will take to develop the trait. The data in tables 1 and 4 do not permit such a fine tuned calculation; however, a related concept can be derived. In particular, for each trait, we took the economic importance score and multiplied it by the speed of development importance score. The product for each trait was then divided by the total of the products for all 12 traits to normalize the calculation to sum to 100. We call the calculation a "priority index." The idea is that a trait that is both economically beneficial *and* can be rapidly developed is one that should rank highly on economic priority.

Because powdery and downy mildew are both perceived as economically important and as traits that can be rapidly developed, they both rate highly on the priority index. Interestingly, early ripening shows up third on the list – because it is perceived as a trait that can be developed relatively rapidly and because it also has relatively high perceived economic benefits.

Table 6. Economic Benefit and Speed of Development Combined

Issue	**Priority Index**
Powdery mildew resistance	46.5%
Downy mildew resistance	22.5%
Early ripening	5.9%
Improved cluster architecture	4.5%
Pierce's disease resistance	4.0%
Drought/heat tolerance	3.8%
5% improvement in yield	3.2%
Vine architecture for mechanization	2.2%
Mid-winter hardiness	2.1%
Reduction in off-aroma compounds	2.0%
Improved balance of sugar/pH/acidity	1.9%
Chilling fulfillment for uniform bud break	1.4%

Other Traits of Interest

At the conclusion of these survey questions, we provided an open ended question in which asked, “Are there important traits that have not been mentioned in this survey thus far, which you believe should be a primary focus of breeding and genetics research?” Sixty-two respondents gave additional, meaningful answers, and each one is listed below in alphabetical order.

	Other Traits of Interest (open response)
1	5% yield is a ridiculously low target for yield enhancement; it's well within the year to year variation in yield for a given vineyard. Try a 25% yield increase. The same holds true for reduction in off flavors--why reduce? Eliminate. Don't fool around, breed grapes.
2	Anthocyanin biosynthesis adapted to warmer climates and malate retention in same and fruit pH lower. Rootstock to restrict water uptake.
3	balance between sugar and phenolic ripening (for red wine grapes)
4	Berry color, berry firmness, berry size, fruit cracking, berry skin texture and astringency (skin is edible or not), seedlessness, berry shelf life, vine vigor
5	berry rot disease
6	berry size; seedless development; berry color development;
7	canker disease resistance
8	Correct annotation of the genome; bioinformatics developments; polymorphism studies
9	crack resistance of berries due to rains near harvest;
10	crown gall disease
11	enhanced root development
12	enhancement of varietal aroma/flavor
13	ESCA and Escoriose
14	Flavor profiles, Phomopsis
15	Flavour and seedlessness for northeastern table grapes; timing of spring budbreak and rate of de-acclimation
16	flavours
17	Frost resistance
18	Fruit Flavor Chemistry, Anthracnose resistance, Foliar Phylloxera Resistance, Economice vine architecture (non-mech)
19	GFLV resistance
20	Grapevine flowering - not just cluster architecture
21	greater winter hardiness
22	Improved salinity tolerance of rootstocks
23	In table grapes, seed content and berry size are the most or very relevant traits and were not listed, as well as post-harvest life and management.
24	in the case of nutraceutical compound, maybe antioxidants concentrations as well as quality traits as berry size and seedlessness
25	late budbreak, earlier fall cold acclimation
26	late ripening
27	many-size, firmness eating quality, seedlessness,skin texture, color for table and raisins
28	Markers to identify cultivar and strain
29	Mid-winter hardiness would be better worded as winter survival. Many locations have a problems at the end of the dormant season, others have it at the beginning of the dormant season and some have mid-winter problems.

30 need more specific aspects of fruit quality
31 Nematode and Phylloxera resistance
32 not many other - question technoques used should be also included to clarify differences among breeding, marker assisted breeding, GMO
33 nothing too important, although canopy architecture for reduction in wetness duration and increased light interception by fruit should be more of a priority than a 5% yield increase
34 Nutrient uptake efficiency, variability in berry set
35 Only if they are done with an understanding of the physiology/management interactions e.g read Webb et al 2012
36 Phomopsis disease, vinifera type leaf shape, muscat wine types, juice yield of wine grapes, insect resistance
37 phylloxera (only a few closely related varieties worldwide), lime induced iron chlorosis, root diseases
38 plasticity to enviromental responce
39 Potassium uptake
40 Powdery mildew
41 rapid, multi-trait (berry color, flower type, disease resistance etc) MAS
42 resistance to black rot, resistance to crown gall
43 Resistance to Downy mildew
44 resistance to phytoplasmas
45 root knot nematode resistance, phylloxera resistance
46 salt toleran roostock
47 seedless
48 Seedlessness
49 seedlessness and aromas in table grapes; nematode resistance and associated virus resistance for rootstocks
50 seedlessness, berry flesh consistency
51 Studies on European Wild Grape
52 The entire questionare is about Euvitis grapes with a strong emphasis on wine grapes. In the southeast we grow muscadines with their own problems.
53 Traits specific to table grape or raisin production
54 uniform cluster ripening
55 virus research
56 Virus resistance
57 Virus resistance
58 virus resistance, nematode resistance, Phylloxera resistance...vigor, graft compatibility...
59 wine quality - positive aroma compounds
60 winequality
61 Yes several. Phomopsis resistance, late bud break, fruitful secondary buds, etc etc.
62 Yes. Phenological adaptation to tropical and subtropical daylength cycles. Everbearing female selections for controlled environment production.

Estimated Cost

Respondents were asked, "What is your best estimate of the annual costs per acre ($/acre) producers in your area spend in an average year to address the following issues?" Then a list of six issues was shown, and respondents answered the question for each.

Table 7. Perceived Cost ($/acre) of six issues (percent of respondents indicating each category of cost)

Issue	less than $1	$1 to $1.99	$2 to $2.99	$3 to $3.99	$4 to $4.99	$5 to $5.99	$6 or more
Powdery mildew	3.9%	0.0%	11.7%	7.8%	3.9%	6.5%	66.2%
Downy mildew	10.5%	1.3%	7.9%	11.8%	3.9%	7.9%	56.6%
Pierce's disease	70.8%	4.2%	1.4%	5.6%	4.2%	1.4%	12.5%
Trunk cankers	47.5%	16.4%	6.6%	0.0%	8.2%	1.6%	19.7%
Black rot	32.8%	11.9%	6.0%	7.5%	9.0%	0.0%	32.8%
Botrytis bunch rot	6.8%	5.4%	5.4%	5.4%	14.9%	8.1%	54.1%

Most of the respondents (66.2%) indicated the costs of powdery mildew were more than $6/acre and a majority (56.6%) also said downy mildew costs were more than $6/acre. Such responses indicate that a higher range of costs would need to be employed to achieve a more accurate estimate of the mean perceived cost of these traits.

However, the results are not totally uninformative. In particular, for those who indicated costs of $6 or more, we know the perceived costs is between $6 and positive infinity. Likewise, respondents who indicated other values provide information on the range of potential costs. We can use these estimates to form intervals around the perceived cost and use interval-censored regressions to estimate the mean (uncensored) cost. When such a procedure is used to calculate the mean cost of powdery mildew, we estimate an average perceived cost of $8.10/acre with a standard deviation of $3.66 assuming a normal distribution on perceived costs per acre. If instead, costs follow a log-normal distribution, our estimates suggest a perceived average cost of $55.57/acre for powdery mildew.

Following the question above, we asked respondents how sure they were of the accuracy of their cost estimates on a scale of 0 to 10 (0 being very unsure and 10 being very sure). The mean across all respondents was 6.45. If we use these answers to provided a weighted perceived cost in the interval censored regression (weighted by the respondent's stated confidence), the mean perceived cost of powdery mildew assuming a normal distribution increases slightly to $8.81/acre.

Questions about Genetics Research

The last section of the survey asked respondents about their use of marker assisted technology and about the perceptions of challenges in genetics research. The list of questions in this section were adapted from a survey conducted by the RosBreed project (A USDA SCRI project on applying marker-assisted breeding to plants in the Rosaceae family - including apple, peach, sweet and tart cherries, and strawberry). The results of the survey of breeders on those commodities can be found here.

Only the sub-set of respondents who said they were directly involved in grape breeding or genetics research answered these questions. Moreover, questions about use or non-use of marker assisted technologies were only answered by people who used or did not use the technology, respectively.

The follow tables report the number of respondents answering in each category. The results are presented without comment as the questions and response categories are self explanatory.

How important or unimportant do you believe are the following factors in influencing the goals of your own breeding program?

	Very Unimportant	Somewhat Unimportant	Neither Important nor Unimportant	Somewhat Important	Very Important	Responses
Consumer preferences	8	9	12	24	30	83
Priorities of funding agencies	12	7	6	21	37	83
fruit/wine/raisin/juice marketer preferences	5	7	15	34	23	84
fruit/wine/raisin/juice wholesaler preferences	7	12	23	28	12	82
personal experiences and interests of breeder	5	7	10	27	35	84
personal experiences and interests of colleagues	7	5	18	36	18	84
plant nursery feedback	7	9	17	30	20	83
grower feedback	6	3	2	32	42	85
organizational directives	12	11	16	29	14	82

What do you believe are the primary difficulties in implementing breeding priorities? (please rank the following eight items by clicking on each item with your mouse and moving the item up or down; 1 = greatest difficulty and 8 = least difficulty)

Statistic	growing difficulties due to environment	lack of funding	lack of time	lack of facilities	lack of available research land	lack of support staff	lack of availability of genetic material	lack of availability of genetic markers
Mean	5.83	1.95	5.10	4.32	5.63	3.96	4.77	4.44
Standard Deviation	1.94	1.47	2.09	1.80	2.04	1.96	2.31	2.28
Total Responses	82	82	82	82	82	82	82	82

What do you believe are the primary difficulties in setting breeding priorities? (please rank the following seven items by clicking on each item with your mouse and moving the item up or down; 1 = greatest difficulty and 7 = least difficulty)

Statistic	lack of available genetic diversity relevant to trait of interest	lack of funding	lack of genetic information	lack of knowledge of commercial viability	lack of communication with interested parties	lack of agreement about trait priorities across interested parties	intellectual property (i.e., unwillingness to share material, lack of access to patented genes, etc.)
Mean	4.44	2.19	3.28	4.64	4.38	4.19	4.88
Standard Deviation	1.90	1.64	1.91	1.65	1.77	1.82	1.94
Total Responses	81	81	81	81	81	81	81

Do you currently use marker-assisted technology?

Answer		Response	%
Yes		46	53%
No		41	47%
Total		87	100%

Why do you use marker-assisted technology? (check all that apply)

Answer		Response	%
cost savings		21	51%
efficiency		36	88%
to establish intellectual property		9	22%
to select parents		25	61%
to confirm identity or relatedness		29	71%

Why do you not use marker-assisted technology? (check all that apply)

Answer		Response	%
cost		13	32%
lack of availability equipment		10	24%
lack of availability of known markers		13	32%
lack of markers associated with trait of interest		13	32%
lack of trained technical support		14	34%
lack of understanding of the technology		5	12%
technology doesn't suit my needs		20	49%
technology doesn't fit my values		1	2%