

Supplemental Data for:

Sambucci O, Alston JM, Fuller KB and Lusk J. 2019.

The pecuniary and nonpecuniary costs of powdery mildew and the potential value of resistant grape varieties in California. *Am J Enol Vitic* 70:177-187. doi: 10.5344/ajev.2018.18032.

Supplemental Table 1 Chemicals used for powdery mildew control. ^a			
Chemical group (active ingredient)	Total pounds applied (2015)^b	Chemical name	Disease pressure
Sulfur compounds	31,217,162	Sulfur Lime-sulfur	All
Contact materials	2,521,482	Potassium bicarbonate Petroleum distillates Neem oil Cinnamaldehyde	All, eradicant
Sterol inhibitors	124,835	Tebuconazole Triflumizole Myclobutanil Fenarimol Triadimefon Difenoconazole	All
Strobilurins	169,354	Azoxystrobin Trifloxystrobin Kresoxim-methyl Pyraclostrobin Boscalid	All
Cell-signaling inhibitor	40,323	Quinoxifen	Low-moderate
Biologicals	19,351	<i>Bacillus sumilus</i> <i>Bacillus subtilis</i> <i>Reynoutra sacalinensis</i> <i>Streptomyces ludicus</i>	All
Multichemical formulations ^c	84,209	Fluopyram+Tebuconazole Difenoconazole+Cyprodinil	All
Benzophenone	44,157	Metrafenone	All
Systemic acquired resistance products	13	Harpin protein L-glutamic acid	Low
Other	35,351	Mancozeb Captan, other related Benomyl	Low-moderate

^aSources: Pesticide Use Reports database (www.cdpr.ca.gov/docs/pur/purmain.htm) list of products used for control of powdery mildew is from UC IPM (2015).^bWeight of active ingredient only.^cExcludes chemicals accounted for in previous categories, such as Tebuconazole and Difenoconazole.

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Supplemental Table 2 Labor and equipment rates and time/acre for a single application, summary of recent UCCE studies.^a

Hourly rates for equipment and labor	Labor (\$/hr)		Equipment (\$/hr)			
	Equipment operators	Field workers	Duster attachment	Sprayer attachment	Tractor for spray applications	Tractor for dust applications
North Coast Region						
Napa–2012	20.3	17.7	n/a	5.8	15.2	15.2
Sonoma–2010	20.1	16.1	10.2	14.3	17.6	17.6
Lake–2008	13.3	10.6	n/a	13.7	16.9	16.9
San Joaquin and Sacramento Valley Regions						
San Joaquin Valley North–2012	16.1	13.4	3.0	3.9	21.8	8.9
San Joaquin Valley South–2008	14.6	11.0	2.8	8.5	10.8	10.8
Sacramento Valley–2013	15.4	12.1	4.6	16.3	22.3	19.9
Time/acre for single application	Dusting sulfur (hr/acre)	Wettable sulfur (hr/acre)	Other fungicides (hr/acre)			
Napa–2012	n/a	1.00	1.00			
Sonoma–2010	0.22	0.38	1.15			
Lake–2008	n/a	0.69	0.69			
San Joaquin Valley North–2012	0.29	0.36	0.36			
San Joaquin Valley South–2008	0.30	0.50	0.50			
Sacramento Valley–2013	0.36	0.39	0.39			

^aSources: Created from the following University of California Cooperative Extension (UCCE) Cost and Return Studies: Sacramento Valley, Chardonnay (UCCE 2013); Napa Valley, Cabernet Sauvignon (UCCE 2012b); Sonoma County, Cabernet Sauvignon (UCCE 2010); San Joaquin Valley, Cabernet Sauvignon (UCCE 2012a); San Joaquin Valley, Organic Raisin Grapes (UCCE 2008); San Joaquin Valley, Thompson Seedless Table Grapes (UCCE 2007); Sonoma, Chardonnay (UCCE 2004); Lake County, Red Varieties (UCCE 2008b); Lake County, White Varieties (UCCE 2008c).

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Supplemental Table 3 Costs (\$/acre) for a single application. ^a			
	Dusting sulfur	Wettable sulfur	Other fungicides
Napa County–2012			
Labor	n/a	24.36	24.36
Equipment		22.48	22.48
Total		46.84	46.84
Sonoma County–2010			
Labor	5.31	9.17	27.74
Equipment	6.50	12.79	38.71
Total	11.81	21.96	66.45
Lake County–2008			
Labor	n/a	11.01	11.01
Equipment		19.16	19.16
Total		30.17	30.17
San Joaquin Valley North–2012			
Labor	5.60	6.95	6.95
Equipment	3.71	10.05	10.05
Total	9.30	16.99	16.99
San Joaquin Valley South–2008			
Labor	5.27	8.78	8.78
Equipment	4.42	10.20	10.20
Total	9.68	18.98	18.98
Sacramento Valley–2013			
Labor	6.65	7.21	7.21
Equipment	9.52	15.93	15.93
Total	16.17	23.14	23.14

^aNotes: In addition to the hours/acre for a single application listed in Supplemental Table 2, a time allowance of 20% is added to calculations of costs/acre for equipment operator labor, and a time allowance of 10% is added to the tractor time to allow for preparation and removal of materials and equipment.

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Supplemental Table 4 Costs (\$/acre) to treat powdery mildew: sample budgets, 2013.^a

Chemical	Central Coast Chardonnay			San Joaquin Valley North table grapes			San Joaquin Valley South raisins		
	Labor	Machinery	Material	Labor	Machinery	Material	Labor	Machinery	Material
Dusting sulfur	n/a	n/a	n/a	6	5	2	7	5	2
Wettable sulfur	n/a	n/a	n/a	6	5	2	7	5	3
Sterol inhibitors	15	11	35	18	14	63	13	10	31
Strobilurins	15	11	45	6	5	67	n/a	n/a	n/a
Cell-signaling inhibitors	8	10	31	n/a	n/a	n/a	n/a	n/a	n/a
Contact	7	5	31	n/a	n/a	n/a	n/a	n/a	n/a

^aSource: Developed from Tables A1 to A12 in Fuller et al. (2014).

Supplemental Table 5 Environmental impact quotient (EIQ) values for chemicals used for powdery mildew control.^a

Chemical category	Chemical name	EIQ/lb chemical			
		Total	Farm worker	Consumer	Ecology
Benzophenone	Metrafenone	n/a	n/a	n/a	n/a
Biologicals	Bacillus pumilus	n/a	n/a	n/a	n/a
	Bacillus subtilis	n/a	n/a	n/a	n/a
	Ampelomyces quisqualis	n/a	n/a	n/a	n/a
Cell signaling inhibitor	Quinoxifen	32.00	10.00	6.00	80.00
Contact materials	Potassium bicarbonate	8.00	6.00	2.00	16.00
	Petroleum distillates	n/a	n/a	n/a	n/a
	Neem oil	n/a	n/a	n/a	n/a
	Cinnamaldehyde	n/a	n/a	n/a	n/a
Multichemical formulatios	Difenoconazole	41.50	15.00	23.50	86.00
	Cyprodinil	26.77	12.15	14.73	53.45
Sterol inhibitors	Tebuconazole	40.33	20.00	31.00	70.00
	Triflumizole	20.42	11.40	6.70	43.15
	Myclobutanil	24.01	8.10	12.15	51.79
	Fenarimol	18.10	12.00	15.00	27.30
	Triadimefon	26.96	12.15	15.15	53.57
Strobilurins	Azoxystrobin	26.92	8.10	6.05	66.62
	Trifloxystrobin	29.78	12.15	10.23	66.95
	Kresoxim-methyl	15.07	9.00	4.50	31.70
	Pyraclostrobin	27.01	8.10	4.05	68.87
	Boscalid	26.44	12.15	21.23	45.95
Sulfur compounds	Sulfur	32.66	21.87	8.29	67.82
	Lime-sulfur	67.67	108.00	19.00	76.00
Systemic acquired resistance products	Harpin protein	n/a	n/a	n/a	n/a
	L-glutamic acid	n/a	n/a	n/a	n/a
Other	Mancozeb	25.72	20.25	8.13	48.79
	Captan, other related	15.77	12.00	5.00	30.30
	Benomyl	30.24	13.80	13.60	63.32

^aSources: Active ingredients for each product were obtained from the Environmental Protection Agency website (<https://www.epa.gov/pesticide-labels>). EIQ values by chemical name and active ingredient are from Eshenaur et al. (1992 to 2015).

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Supplemental Table 6 Values of the environmental impact quotient (EIQ) for non-powdery mildew chemicals used on grapes.^a

Category/product name (active ingredient)	EIQ/lb chemical			
	Total	Farm worker	Consumer	Environment
Fungicides				
Champ (copper hydroxide)	33.20	24.30	9.05	66.25
Vanguard (cyprodinil)	26.77	12.15	14.73	53.45
Applaud (buprofezin)	34.97	12.00	19.00	73.90
Insecticides				
AgriMek (abamectin)	34.68	13.80	3.90	86.35
Altacor (chlorantraniliprole)	18.34	6.90	6.45	41.66
Intrepid (methoxyfenozide)	32.08	10.00	8.00	78.25
Kryocide (cryolite)	20.16	13.11	4.99	42.37
Lorsban (clorpyrifos)	26.85	6.00	2.00	72.55
Movento (spirotetramat)	35.29	13.11	5.99	86.77
Provado (imidacloprid)	36.71	6.90	10.35	92.88
Herbicides				
Rely (glufosinate-ammonium)	20.20	12.00	6.00	42.60
Roundup, Glyphos (isopropylamine salt of glyphosate)	15.33	8.00	3.00	35.00
Surflan (oryzalin)	18.10	9.00	6.00	39.30
Other				
Acramite (bifenazate)	28.10	6.90	2.45	74.95
Ethrel (ethephon)	24.80	21.30	5.65	47.45
Neutral zinc (zinc, sulfur)	32.66	21.87	8.29	67.82

^aSources: Active ingredients for each product were obtained from the Environmental Protection Agency website (<https://www.epa.gov/pesticide-labels>). EIQ values by chemical name and active ingredient are from Eshenaur et al. (1992 to 2015).

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Supplemental Table 7 Summary demographic characteristics of survey respondents.

Characteristic	Respondents	Percent
Category of grapes		
Wine	60	0.56
Table	18	0.17
Raisin	11	0.10
Unknown	19	0.18
Region		
Unknown	9	0.08
North Coast	26	0.23
Central Coast	3	0.03
Southern Central Valley	16	0.14
Nothern Central Valley	3	0.03
Other California	15	0.13
Acres managed		
Fewer than 10	16	0.21
10 to 49	12	0.16
50 to 99	6	0.08
100 to 199	6	0.08
200 to 299	6	0.08
300 to 399	8	0.11
400 to 799	6	0.08
Over 800	16	0.21
Gender		
Male	49	0.89
Female	6	0.11
Education		
Bachelor's degree	53	0.49
Graduate degree	15	0.14
Income Level		
Less than \$50,000	4	0.09
\$50,000 to \$99,000	3	0.07
\$100,000 to \$149,000	13	0.28
\$150,000 to \$199,000	11	0.24
\$200,000 to \$299,000	9	0.20
\$300,000 or more	7	0.15
Unknown	6	0.13

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Supplemental Table 8 Importance of attributes scale questions.

How important or unimportant is it that your vineyard uses vines (rootstock and scions) that have the following characteristics? <i>(Please check a box for each characteristic.)</i>	Very unimportant	Somewhat unimportant	Somewhat important	Very important	N/A
Increase yield (tons produced per acre)					
Produce a consistent yield from year-to-year					
Be of a recognizable variety					
Delay budbreak (for frost protection)					
Reduce the need to apply insecticides					
Be resistant to herbicide					
Reduce the need to spray fungicides					
Facilitate the use of mechanized harvesting					
Be more tolerant to frost and cold					
Be more tolerant to heat					
Be more tolerant to drought					
Be more tolerant to wet soil conditions					
Ripen more uniformly					
Produce more uniform berry shape and size					
Produce looser grape clusters					
Improved acid/sugar balance in fruit					
Produce fruit with more acidity					
Produce fruit with improved flavor or aroma					
Ripen in a particular harvest window					
Produce uniform and consistent colored fruit					

Supplemental Table 9 Experimental design.

Attribute	Option A (not powdery mildew [PM] resistant)	Option B (PM resistant)
Price (\$/vine)	\$2, \$3, \$4, or \$5	\$2, \$3, \$4, or \$5
Resistant to PM?	No	Yes
Genetically modified?	No	Yes or No
Variety	Chardonnay	“Chardonnay-like” (if non-genetically modified [GM]) or Chardonnay (if GM)
Number of fungicide applications/yr	1, 3, or 6 applications/yr	0 applications/yr
Changes in environmental impact	0, -50%, or -100%	-100%
Changes in impact on worker health	0, -50%, or -90%	-100%

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Grape Grower Survey



Grape Grower Survey

Investigator: Julian Alston, Ph.D., University of California, Davis

Purpose: This study is meant to identify grower perceptions and preferences to help guide current and future grape genetics research. The responses will be used to inform participants involved in a project funded by a USDA-Specialty Crop Research Initiative grant supported with industry funding.

Procedures: Proceeding with the survey will imply your consent to participate in this study. There are 21 questions asking about your preferences and characteristics of your operation. The survey will take about 15 minutes to complete.

Risks of Participation: The risks associated with this study are minimal. The risks are not greater than those ordinarily encountered in daily life. Moreover, you may skip any survey items that you perceive as threatening or discomforting; you may also stop at any time.

Benefits: This research will aid in understanding and prioritizing grape genetics research.

Confidentiality: The researchers will not have access to your name. At no point will a data file be constructed in which your name is linked with your responses. The data will be stored by the principal investigator in his office with no intention to destroy the data. The data will only be released in summaries in which no individual's answers can be identified.

Contacts: If you have any questions or concerns about this project, please contact Dr. Julian Alston, (530) 752-3283, julian@primal.ucdavis.edu.

Participant Rights: Your participation in this research is voluntary. You can discontinue the survey at any time without reprisal or penalty.

If you choose to participate: Returning your completed survey indicates your willingness to participate in this research study.

You may return this survey in person to our representative or by mail:

If you choose to return this survey by mail, please mail to:

**Prof. Julian Alston
Agricultural and Resource Economics
UC Davis
2157 Social Sciences and Humanities
1 Shields Avenue
Davis, CA 95616**

1. Are you a grape producer?

- Yes: → Please check the type of grapes you produce (Please check all that apply)
- Wine
 - Table
 - Raisin
- No → if no, please stop now and return the survey

2. How important or unimportant is it that your vineyard uses vines (rootstock and scions) that have the following characteristics? (please check a box for each characteristic)

	Very Unimportant	Somewhat Unimportant	Somewhat Important	Very Important	N/A
Increase yield (tons produced per acre)					
Produce a consistent yield from year-to-year					
Be of a recognizable variety					
Delay budbreak (for frost protection)					
Reduce the need to apply insecticides					
Be resistant to herbicide					
Reduce the need to spray fungicides					
Facilitate the use of mechanized harvesting					
Be more tolerant to frost and cold					
Be more tolerant to heat					
Be more tolerant to drought					
Be more tolerant to wet soil conditions					
Ripen more uniformly					
Produce more uniform berry shape and size					
Produce looser grape clusters					
Improved acid/sugar balance in fruit					
Produce fruit with more acidity					
Produce fruit with improved flavor or aroma					
Ripen in a particular harvest window					
Produce uniform and consistent colored fruit					

3. Over the past five years, what is your target average annual yield (tons per acre)?

tons/acre

4. Over the past five years, what was the average price you received per ton of your grapes (\$/ton of fresh grapes)?

5. Do you live on the same property as a vineyard you manage? Yes No
6. How many vineyard acres do you manage? (if you operate more than one vineyard, please answer according to the sum of all acres you manage)
- Less than 10 acres
 - 10 to 49 acres
 - 50 to 99 acres
 - 100 to 149 acres
 - 150 to 199 acres
 - 200 to 299 acres
 - 300 to 399 acres
 - 400 to 599 acres
 - 600 to 799 acres
 - 800 to 999 acres
 - 1000 to 1499 acres
 - 1500 to 1999 acres
 - 2000 acres or more
7. Over the past five years, on average how often did you apply fungicides to treat for powdery mildew each year?
- 0 to 2 times per year
 - 3 to 5 times per year
 - 6 to 8 times per year
 - 9 to 11 times per year
 - 12 to 14 times per year
 - 15 to 17 times per year
 - 18 times per year or more
8. What is the *primary* outlet for the grapes you produce?
- Grapes sold under a predetermined contract to a winery or other wine producer
 - Grapes sold under contract to a grape processor other than wine
 - Grapes sold on the open market at harvest
 - Grapes used for own wine production
 - Grapes sold for juice
 - None of the above
9. Over the past five years, what is your best estimate of the average annual costs (including labor, equipment, chemical, fuel, etc.) that you spent treating for powdery mildew?
- \$0 to \$49 per acre per year
 - \$50 to \$99 per acre per year
 - \$100 to \$149 per acre per year
 - \$150 to \$199 per acre per year
 - \$200 to \$249 per acre per year
 - \$250 to \$299 per acre per year
 - \$300 to \$349 per acre per year
 - \$350 to \$399 per acre per year
 - \$400 to \$449 per acre per year
 - \$450 to \$499 per acre per year
 - \$500 to \$549 per acre per year
 - \$550 to \$599 per acre per year
 - \$600 per acre per year or more

➤ We are now going to ask you eight repeated questions about your preferences for hypothetical types of vines or selections that geneticists and breeders might develop to work with new pesticides in assisting with powdery mildew resistance. Imagine you are selecting new vines for your primary vineyard. For simplicity sake, assume you have chosen to plant a Chardonnay or Chardonnay-like variety (a variety that is very similar to Chardonnay in all relevant characteristics).

In each question, you are presented with two hypothetical options: Option A and Option B. Below each option is a list of the characteristics of the option. We want to know which of the two options you would prefer if they were the only options available to you. Each option varies by:

- price of the vines
- whether the vines are genetically resistant to powdery mildew,
- whether the vines have been genetically modified,
- the expected number of fungicide applications required for the vines, and
- the expected environmental and health impacts resulting from the fungicide applications.

For options that are conventionally bred to be resistant to powdery mildew, the resulting vine cannot carry the Chardonnay varietal name; we simply refer to such varieties as ‘Chardonnay like’.

10. Of the two vine selections shown below, would you be most likely to purchase option A or option B? (please check only one of the two options below)

Characteristic	Grapevine A	Grapevine B
Price	\$5/vine	\$3/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	No
Variety	Chardonnay	'Chardonnay-like'
Expected Number of Fungicide Applications	3 times/year	0 times/year
Environmental Impact of Fungicide Applications	same as at present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	same as at present	100% reduction relative to present
I prefer . . . (place a √ or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

11. Of the two vine selections shown below, would you be most likely to purchase option A or option B? (please check only one of the two options below)

Characteristic	Grapevine A	Grapevine B
Price	\$4/vine	\$2/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	Yes
Variety	Chardonnay	Chardonnay
Expected Number of Fungicide Applications	1 time/year	0 times/year
Environmental Impact of Fungicide Applications	same as at present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	90% reduction relative to present	100% reduction relative to present
I prefer . . . (place a √ or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

12. Of the two vine selections shown below, would you be most likely to purchase option A or option B? *(please check only one of the two options below)*

Characteristic	Grapevine A	Grapevine B
Price	\$2/vine	\$5/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	No
Variety	Chardonnay	'Chardonnay-like'
Expected Number of Fungicide Applications	6 times/year	0 times/year
Environmental Impact of Fungicide Applications	100% reduction relative to present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	90% reduction relative to present	100% reduction relative to present
I prefer ... (place a \checkmark or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

13. Of the two vine selections shown below, would you be most likely to purchase option A or option B? *(please check only one of the two options below)*

Characteristic	Grapevine A	Grapevine B
Price	\$3/vine	\$5/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	No
Variety	Chardonnay	'Chardonnay-like'
Expected Number of Fungicide Applications	1 time/year	0 times/year
Environmental Impact of Fungicide Applications	same as present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	50% reduction relative to present	100% reduction relative to present
I prefer ... (place a \checkmark or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

14. Of the two vine selections shown below, would you be most likely to purchase option A or option B? *(please check only one of the two options below)*

Characteristic	Grapevine A	Grapevine B
Price	\$5/vine	\$2/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	Yes
Variety	Chardonnay	Chardonnay
Expected Number of Fungicide Applications	6 times/year	0 times/year
Environmental Impact of Fungicide Applications	100% reduction relative to present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	same as present	100% reduction relative to present
I prefer ... (place a \checkmark or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

15. Of the two vine selections shown below, would you be most likely to purchase option A or option B? *(please check only one of the two options below)*

Characteristic	Grapevine A	Grapevine B
Price	\$5/vine	\$3/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	No
Variety	Chardonnay	'Chardonnay-like'
Expected Number of Fungicide Applications	6 times/year	0 times/year
Environmental Impact of Fungicide Applications	50% reduction relative to present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	50% reduction relative to present	100% reduction relative to present
I prefer ... (place a \checkmark or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

16. Of the two vine selections shown below, would you be most likely to purchase option A or option B? *(please check only one of the two options below)*

Characteristic	Grapevine A	Grapevine B
Price	\$3/vine	\$4/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	Yes
Variety	Chardonnay	Chardonnay
Expected Number of Fungicide Applications	3 times/year	0 times/year
Environmental Impact of Fungicide Applications	100% reduction relative to present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	50% reduction relative to present	100% reduction relative to present
I prefer ... (place a \checkmark or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

17. Of the two vine selections shown below, would you be most likely to purchase option A or option B? *(please check only one of the two options below)*

Characteristic	Grapevine A	Grapevine B
Price	\$2/vine	\$4/vine
Resistant to Powdery Mildew?	No	Yes
Genetically Modified?	No	Yes
Variety	Chardonnay	Chardonnay
Expected Number of Fungicide Applications	1 time/year	0 times/year
Environmental Impact of Fungicide Applications	50% reduction relative to present	100% reduction relative to present
Impact of Fungicide Application on Worker Health	same as present	100% reduction relative to present
I prefer ... (place a \checkmark or X in the box under A or B)	<input type="checkbox"/>	<input type="checkbox"/>

➤ **Finally, we would like some background information. This is an important part of our analysis. The survey is anonymous and your name is not linked to the responses.**

18. What is your gender?

- Male
- Female

19. Have you obtained a Bachelor's degree from a university or college?

- Yes
- No

20. What is your approximate annual household income before taxes last year?

- Less than \$50,000
- \$50,000 to \$99,999
- \$100,000 to \$149,999
- \$150,000 to \$199,999
- \$200,000 to \$299,999
- \$300,000 or more

21. What is your present age? years

22. In which California county do you live? county

Thank you for your help! Please return your survey.