Factors Influencing the Adoption of Russian Varroa-Resistant Honey Bees

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Abstract

Factors influencing the adoption of Russian *Varroa*-Resistant honey bees were assessed. Logit results indicate factors associated with the adoption include sales, internet use, and contact with other beekeepers. Negatively associated factors are age and income. Future adoption depends upon previous use and perception.

Keywords: Adoption, Logit, Russian *Varroa*-Resistant honey bees

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Background

A parasitic mite, *Varroa destructor*, has been and continues to be a significant problem for beekeepers. *Varroa* mite infestations have been responsible for significant declines in beekeeping numbers as most affected colonies eventually die if not treated. USDA Census of Agriculture data from 1987 through 1997 indicated one-half of the farms with honey sales or bee colonies exited the beekeeping industry during that period. Accompanying the decline in farm numbers was a 17% reduction in the number of bee colonies and honey production from 1987 to 1997 (USDA).

Until recently, beekeepers' options for controlling *Varroa* mites were limited to certain chemicals (fluvalinate and coumaphos). Because *Varroa* mites have developed localized resistance to these chemicals, their future effectiveness in the US is tenuous at best. Research scientists at the USDA-ARS have identified and selectively bred queens from a line of Russian honey bees that are resistant to *Varroa* mites. This new technology provides beekeepers with another option for controlling *Varroa* mites. The commercial release of this line of queens of Russian honey bees presented some important questions about the level of adoption of this technology and identification of factors influencing the adoption decision.

Objectives

The objectives of the study are to: (1) assess the extent of current adoption of Russian *Varroa*-resistant queen bees in the honey beekeeping industry; (2) determine the factors affecting future adoption of Russian *Varroa*-resistant bees; (3) determine the effect of demographic, socioeconomic, and farm characteristics on the adoption of Russian *Varroa*-resistant bees; and (4) provide policy recommendations based on the empirical results.

Methods

With a discrete choice modeling technique, factors critical in the decision to adopt Russian queens were assessed. A beekeeper would choose to adopt Russian *Varroa*-Resistant bees if his or her utility from the adoption is greater than or equal to the utility from non-adoption.

Limited dependent variable models such as probit or logit can be used to determine the factors that affect adoption of new technology. Since the utility associated with a new technology is unobservable, what we observe is the actual adoption or non-adoption of that technology. The probability of choosing to adopt over not to adopt can be expressed as in equation (1) (Greene).

$$(1) \qquad P_i = prob\ (Y_i=1|X) = \frac{\exp(\sum \beta X_i)}{\left[1+\exp(\sum \beta X_i)\right]} = \Lambda(X_i'\beta)$$

where Y represents whether or not the technology was adopted, X is a set of explanatory variables that affect the adoption decision, β represents parameters of X to be estimated, and Λ is a logistic cumulative distribution function.

The effect of an independent variable on the dependent variable is measured by marginal effects, holding all other variables constant. The marginal effect of a kth continuous variable can be derived using equation (2):

$$(2) \qquad \frac{\partial P_i}{\partial X_{ik}} = \Lambda(X'\beta)[1-\Lambda(X'\beta)]\beta\ .$$

Marginal effects for dummy variables, Δ, can be derived as (3) (Greene)

$$(3) \qquad \Delta = prob[Y=1 \mid \overline{X}, d=1] - prob[Y=1 \mid \overline{X}, d=0]$$

where $\overline{X}$ represents the means of all continuous X variables and the modal value of the other dummy variables, and *d* is a dummy variable.

Data

To carry out the purposes of this study, a mail survey and an on-line survey were used. For the mail survey, names of honey beekeepers were obtained from membership lists of the American Beekeeping Federation (ABF) and the American Honey Producers Association (AHPA). After deleting names of companies, researchers from universities, associations, and duplicates from both groups, a total of 1,030 producers were used for the mail survey. The survey design and protocol followed recommendations by Dillman. Through five contacts, 502 usable observations were obtained. One-hundred-nine respondents indicated that they were no longer in the business or indicated that they were ineligible for the survey with various reasons. Eleven responses were unusable. The response rate was 55 percent after deducting 120 from the sample.

To complement the effort, and to obtain information from beekeepers who were not members of either association, an internet survey was conducted. Brief information about the online survey was provided to beekeepers through two honey beekeeping related journals (in the April, 2005, issues of both the American Bee Journal and Bee Culture). Effort was made to contact 50 state apiarists and 543 beekeeping clubs about the survey through e-mails and surface mail (a sample questionnaire was included). A total of 299 cases were obtained from web survey in addition to sixteen respondents who also received the questionnaire by mail. Eighteen of 299 cases were unusable. Twenty-three additional responses came in through mail from the representatives of beekeeping clubs who received a sample questionnaire. A total of 806 observations were obtained from mail and on-line surveys.

Factors Affecting the Adoption of Russian *Varroa*-Resistant Bees

Farm size has received extensive attention in the adoption of technological innovations in agriculture (Feder et al.). Feder et al. noted that the relationship between technology adoption and farm size relies on factors such as fixed adoption costs, human capital, and credit constraints. Larger farms have advantages in new technology adoption since they may have lower credit constraints. Foltz and Chang found that farm size (measured in number of cows per farm) had a positive and significant relationship with the adoption of recombinant bovine somatotropin on Connecticut dairy farms. The adoption of a new line of bees seems not to require substantial new fixed costs. However, accessing information can be considered as a fixed cost, as noted by Feder et al. In fact, researchers have proven this through studies on the adoption of high yield varieties, which seem scale neutral (Parthasarathy and Prasad; and Perrin and Winkelmann). For these reasons, larger-sized beekeepers are expected to more likelyadopt Russian-*Varroa* Resistant bees than smaller-sized beekeepers. We used the number of bee colonies kept as a size variable.

Beekeepers' attitudes on new technology may differ greatly depending upon whether they are hobbyists or commercial beekeepers. Commercial beekeepers are expected to seek and adopt new technology more rigorously. We used a dummy variable indicating whether the beekeeper sold more than $1,000 in bee-related products as a proxy.

The primary manager's level of education is hypothesized to affect adoption of new technology. Huffman demonstrated that higher educated farmers have greater allocative ability and respond more efficiently to change. Thus, the primary manager holding a college bachelor's degree was hypothesized to have positive relationship with adoption of Russia-*Varroa* Resistant bees.

Education includes both formal school education and learning through extension. Kim et al. found positive relationships between the adoption of best management practices (BMPs) and farmers' contact with the Natural Resources Conservation Service, and extension agents dealing with BMPs. Bhattacharyya et al. showed a significant impact of an extension program on the adoption of the trichomoniasis vaccine by cattle producers. Gooodwin and Schroeder used a seminar attendance variable, finding significance in the adoption of forward pricing. It is hypothesized that beekeepers with greater numbers of contacts with USDA and state departments of agriculture (SDA) are more likely to adopt Russian-*Varroa* Resistant bees. Since Russian *Varroa*-Resistant bees were developed by researchers with the USDA Agricultural Research Service, USDA has informed beekeepers about the Russian bees through their website and via seminars. Therefore, for beekeepers with frequent contact with USDA, the likelihood of adoption is expected to be greater. State department of agriculture apiculturists inspect bee hives on a regular basis and host beekeeping club meetings in some states. For these reasons, the numbers of contacts, which include meeting attendance, seminars or workshops, and in-person contact, with USDA and SDA have been hypothesized to have positive relationships with the adoption of Russian bees.

The primary manager's age has been used as an explanatory variable in many adoption studies. Zepeda found age to be significant in bovine somatotropin adoption. Younger dairy farmers were more likely to adopt the technology than older farmers. On the other hand, Soule et al. found a negative relationship between farmers' age and the adoption of conservation practices, many of which were not "new" technologies and which older farmers had more time to have adopted. Older beekeepers are expected to be less likely to adopt the new Russian *Varroa*-Resistant bees.

A new technology's diffusion depends on its availability. Russian *Varroa*-Resistant bees were released in 2000, and the technology is still in the introduction stage. Newly-introduced queens may be difficult to produce in large number in the short run. In fact, availability was limited at the time of survey. The primary residence of beekeepers can make a difference in adoption because availability may still be limited to certain states. Since Russian *Varroa*-Resistant bees were developed at the ARS bee lab in Baton Rouge, Louisiana, states nearer to this location have an advantage in obtaining Russians. Beekeepers' primary residence in the Delta states (Mississippi, Arkansas, and Louisiana) is expected to have a positive relationship with the adoption of Russian *Varroa*-Resistant bees.

Beekeepers' opinions on the *Varroa* mite problem in their operations may affect their adoption of alternative lines of bees. Beekeepers have been treating their infected colonies with chemicals; however this type of treatment has limitations and the mites may have developed resistance to the chemicals. In cases where this has occurred, beekeepers would look for alternative lines of bees which have resistance to the mites. Therefore, beekeepers who experience severe *Varroa* mite problems are expected to more likely adopt Russian *Varroa*-Resistant bees.

Farmers with personal computers and internet access can get technical information on beekeeping, and may learn about different lines of bees and adopt them. Zepeda demonstrated that dairy farmers who used computer record keeping were early adopters of bovine somatotropin. Bhattacharyya et al. found consistent results with Zepeda's study, showing that cattle producers who used personal computers were more likely to be immediate adopters of the trichomoniasis vaccine. There is another aspect that increases the likelihood of adoption by internet users. In the U.S., internet use in rural areas is not as common as in urban areas. Thus,

internet users in rural areas are considered as early adopters of the internet. Innovators or early adopters (Rogers) of new technology may be more apt to adopt other technologies, as well. For these reasons, internet users are expected to more likely adopt Russian *Varroa*-Resistant bees.

The influence of fellow farmers or neighbors has been discussed in the adoption literature. Baerenklau found that peer-group influence is relatively less important than risk preferences and learning in the adoption of intensive rotational grazing by Wisconsin dairy farmers. In the present study, the number of beekeepers that a beekeeper discusses technical beekeeping issues with is used to measure peer-group influence. Unlike Baerenklau's study, we expect beekeepers who discuss industry issues with a greater number of fellow beekeepers to be the greater adopters of Russian *Varroa*-Resistant bees.

Financial situation may affect the adoption decision even in the adoption of a scale-neutral technology. Beekeepers with higher household incomes are expected to adopt Russian *Varroa*-Resistant bees. Beekeepers who have higher percentages of income coming from beekeeping are expected to adopt Russian *Varroa*-Resistant bees. Membership in a beekeeping group or society may affect the adoption of new lines of bees. AHPA and ABF host annual conventions, maintain websites, and issue beekeeping-related magazines. Members of these groups may have better access to information about new technology on beekeeping. We include membership in AHPA as a binary dummy variable and use membership in ABF as a base.

Beekeepers' decisions on adoption of a specific line of bees would also depend on their perceptions of the line and their previous adoption decisions. Thus, additional explanatory variables, two perception variables and a variable indicating previous adoption of Russian *Varroa*-Resistant bees, were used for the estimation of the future adoption of Russian *Varroa*-Resistant bees. The two perception statements used in the estimation include, "Russian queens

help control *Varroa* mites better than other queens," and "Colonies with Russian queens are more difficult to manage than colonies with other queens."

Results

Thirty-six percent of the beekeepers responded that they had adopted Russian *Varroa*-Resistant bees, while 40 percent responded that they plan to use them in the future. Evidence that beekeepers perceive *Varroa* mites to be a "very serious problem" is shown in Table 1. Two-thirds of the beekeepers indicated *Varroa* mites were a "very serious" or "extremely serious" problem in their operations; almost one-half (46%) indicated the problem was "extremely serious."

Table 2 presents a description and summary statistics of explanatory variables. On average, 700 bee colonies were kept by the beekeepers in 2004. Sixty-seven percent of the respondents sold at least $1,000 of beekeeping-related products. Almost half of the respondents held a college bachelor's degree. Beekeepers on average had just under one contact with USDA, and almost two contacts with state departments of agriculture in 2004. Average age of the respondents was 56. Four percent of the beekeepers represented were from the Delta states. Sixty-four percent of respondents indicated a Likert-scale value of 4 or 5, 5 representing an "extremely serious problem," to the statement asking how serious the *Varroa* mite problem was. Sixty-four percent used the internet to obtain technical information on beekeeping. Beekeepers had an average of ten fellow beekeepers with whom they discussed technical beekeeping issues. Fifty-two percent of respondents indicated they had at least $60,000 of household net income in 2004.

Twenty percent of respondents indicated that their annual household income coming from the beekeeping operation was greater than 60 percent. Twenty-four percent of respondents

indicated that they were members of AHPA. Thirty-four percent marked 4 or 5, 5 representing "strongly agree," on the statement "Russian queens help control *Varroa* mites better than other queens." Finally, 32 percent of respondents marked 4 or 5, 5 representing "strongly agree," on the statement, "Colonies with Russian queens are more difficult to manage than colonies with other queens."

Table 3 presents logit model results on the adoption of Russian *Varroa*-Resistant bees. A weighting variable was used to match with the proportion of the beekeeper population by each state. The number of colonies kept was not a significant factor. However, a dummy variable indicating sales of more than $1,000 was positive and significant. Thus, the number of colonies kept is not a decisive factor on the adoption of Russian bees, but beekeepers who sold more than $1,000 are more likely to adopt Russian bees.

Beekeepers' holding of a college degree was not a significant factor in the adoption of Russian bees. The numbers of contacts with USDA and SDA were expected to have positive relationships with the adoption of Russian bees. However, only the number of contacts with SDA was significant. The results show that beekeepers adopt new technology according to extension outreach. Beekeeper's age had a negative and significant relationship with the adoption of Russian *Varroa*-Resistant bees, as expected. As beekeepers aged by ten year, the likelihood of adoption declined by four percent. The negative relationship between age and adoption is consistent with most studies dealing with the adoption of new technologies.

Delta beekeepers are more likely to adopt Russian bees. As mentioned earlier, the location of residence can be an obstacle to adoption. Russian bees were not widely available at the time of survey. The likelihood increases by 40 percent when the beekeeper's primary residence is Arkansas, Mississippi, or Louisiana. Beekeepers who indicated that they were

having serious *Varroa* mite problems were expected to adopt Russian *Varroa*-Resistant bees. However, the binary variable was not significant.

The variable indicating beekeepers who used the internet to get technical information on beekeeping had a significant and positive sign, as expected. Many queen suppliers run a website and take on-line orders. Thus, internet users may learn about Russian queens through websites and may order them. Computer adopters tend to be adopters of technology, consistent with findings of Zepeda. The variable indicating the number of beekeepers with whom the respondent discussed technical beekeeping issues had a positive and significant relationship with adoption of Russian bees. As beekeepers had one more beekeeper with whom they discuss beekeeping issues, the likelihood of adoption increased by one percent. Household income was significant, though the negative sign was unexpected. A dummy variable on AHPA membership had a positive relationship with the adoption of Russian bees. Members of AHPA were 20 percent more likely to adopt Russian bees than non-AHPA members.

Logit results on the future adoption of Russian *Varroa*-Resistant bees are presented in table 4. The positive and significant factors on the future adoption of Russian *Varroa*-Resistant bees include two dummy variables representing beekeepers who agreed with "Russian queens help control *Varroa* mites better than other queens," and beekeepers who have kept Russians in the past years. The negative and significant factors include dummy variables representing beekeepers' agreement with "Colonies with Russian queens survive the winter better than colonies of the other queens," and having more than 60 percent of income coming from beekeeping. Perception variables were strongly significant in the future adoption decisions of Russian *Varroa*-resistant queens.

Beekeepers who had experience with Russian queens perceived the bees as not very difficult to manage compared to beekeepers who had never kept them (Table 5). Respondents who had experience with Russian queens were not statistically different from those with no experience on the statement, "Colonies with Russian queens survive the winter better than colonies with other queens," and "Colonies with Russian queens produce more honey than colonies of other queens."

Conclusions

The *Varroa* mite problem is becoming more serious in the U.S. beekeeping industry. American honey production is dependent upon how we manage the mite problems. The majority of surveyed beekeepers expressed that the *Varroa* mite problem is an "extremely serious problem." Various efforts are being made to control the mite problem. USDA-ARS has developed and released Russian *Varroa*-Resistant honey bees. Even though it is still in the introduction stage, it is worthwhile to investigate the factors affecting its adoption. Current and future adoption models have been presented in this study using mail and internet survey results.

Factors associated with increased adoption include: sales of over $1,000 of beekeeping related products, frequent contacts with state departments of agriculture, having residency in the Delta states, use of the internet to get technical information on beekeeping, having a greater number of fellow beekeepers with whom to discuss beekeeping issues, and holding membership in the AHPA. Factors negatively associated with adoption include age and household income. The future adoption of Russian *Varroa*-Resistant bees greatly depends upon previous use of Russian *Varroa*-Resistant bees, beekeeper perceptions on their management difficulty and control of the *Varroa* mite.

Availability and difficulty of adoption may have been obstacles for adoption at the time of the survey. The availability problem may be dissolved as more queen suppliers breed and sell Russian *Varroa*-resistant bees. In terms of difficulty, respondents who kept Russian bees thought they were less difficult to use than did those who had not kept Russian bees. Difficulty in management may be resolved via education using various extension efforts.

Making Russian *Varroa*-Resistant bees known to beekeepers is needed since more than 40 to 50 percent of beekeepers indicated they "Don't know" about the four statements on them. One drawback of this study is that the beekeepers using a Russian-hybrid may have marked that they had used Russian *Varroa*-Resistant bees. Further study should involve intensity of adoption, because beekeepers who are using Russian *Varroa*-Resistant bees are likely using them in only part of their operations.

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Table 1. Beekeepers Opinions on the *Varroa* Mite Problem.

	Not a problem				Extremely serious problem	Don't Know
Likert-Scale	1	2	3	4	5	
Respondents	69	87	126	170	311	35
Percent	(9%)	(11%)	(16%)	(21%)	(39%)	(4%)

Table 2. Description and Summary Statistics of Explanatory Variables. (n=632)

Variable	Description	Mean	Std. Div.
Colonies	Number of bee colonies kept in 2004 divided by 100	7.041	19.880
Sales_$1000	1 if a beekeeping operation had over $1,000 sales of beekeeping related products, zero otherwise.	0.672	0.470
College	1 if a respondent holds a college bachelor's degree, zero otherwise.	0.453	0.498
USDA	Number of contacts with USDA in 2004.	0.984	3.128
SDA	Number of contacts with State Departments of Agriculture in 2004.	1.793	3.527
Age	Years in age of respondents divided by 10.	5.621	1.244
Delta	1 if a beekeeper's primary residence is Arkansas, Louisiana, or Mississippi; zero otherwise.	0.035	0.183
Varroa_serious	1 if a respondent marked either 4 or 5 (extremely serious problem) in a Likert-scale measurement on the extent of *Varroa* mite problem, zero otherwise.	0.638	0.481
Internet	1 if a respondent uses the internet to get technical information on beekeeping, zero otherwise.	0.636	0.482
Beekeepers	Number of beekeepers with whom to discuss technical beekeeping issues.	9.185	7.282
Inc_$60,000	1 if a respondent had annual household net income greater than or equal to $60,000, zero otherwise.	0.516	0.500
Bkeeping_60%	1 if a respondent's income coming from beekeeping is greater than 60 percent, zero otherwise.	0.203	0.402
AHPA	1 if a respondent is a member of AHPA, zero otherwise.	0.237	0.426
Kept_Rus	1 if a respondent has kept Russian *Varroa*-Resistant bees.	0.364	0.482
Rus_Varroa	1 if a respondent marked either 4 or 5 (strongly agree) in a Likert-scale measurement to the statement "Russian queens help control *Varroa* mite better than other queens," zero otherwise	0.338	0.474
Rus_difficult	1 if a respondent marked either 4 or 5(strongly agree) in a Likert-scale measurement to the statement "Colonies with Russian queens are more difficult to manage than colonies with other queens," zero otherwise.	0.320	0.467

Table 3. Logit Results on the Adoption of Russian *Varroa*-Resistant Bees. (n=632)

Variable	Coefficient	Standard Error	Marginal Effects	Standard Error of Marginal Effects
Constant	-0.990*	0.578	-	-
Colonies	0.004	0.006	0.001	0.001
Sold_$1000	0.636**	0.248	0.145***	0.054
College	0.212	0.216	0.050	0.051
USDA	0.044	0.032	0.010	0.008
SDA	0.047*	0.029	0.011*	0.007
Age	-0.183**	0.093	-0.043*	0.022
Delta	1.713***	0.543	0.396***	0.099
Varroa_serious	0.251	0.232	0.059	0.054
Internet	0.460**	0.224	0.106**	0.051
Beekeepers	0.042**	0.017	0.010**	0.004
Income_$60,000	-0.475**	0.229	-0.111**	0.054
Beekeeping_60%	-0.200	0.325	-0.046	0.074
AHPA	0.812***	0.239	0.197***	0.058
McFadden's R^2	0.114			

*, ** and *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 4. Logit Results on the Future Adoption of Russian *Varroa*-Resistant Bees. (n=582)

Variable	Coefficient	Standard Error	Marginal Effects	Standard Error of Marginal Effects
Constant	-0.767	0.640	-	-
Kept_Rus	1.256***	0.239	0.300***	0.054
Rus_Varroa	1.679***	0.248	0.395***	0.053
Rus_difficult	-0.644**	0.260	-0.152**	0.059
Colonies	-0.002	0.007	-0.0004	0.002
Sales_$1000	0.054	0.266	0.013	0.064
College	-0.113	0.242	-0.027	0.058
USDA	-0.055	0.042	-0.013	0.010
SDA	0.021	0.034	0.005	0.008
Age	-0.057	0.093	-0.014	0.023
Delta	0.427	0.469	0.106	0.117
Varroa_serious	0.123	0.247	0.030	0.059
Internet	0.348	0.249	0.083	0.058
Beekeepers	-0.017	0.017	-0.004	0.004
Income_$60,000	-0.258	0.244	-0.062	0.059
Beekeeping_60%	-0.840**	0.370	-0.188**	0.074
AHPA	-0.154	0.282	-0.037	0.067
McFadden's R^2	0.189			

*, **, and *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 5. Mean of Likert-Scale on Perception of Russian Queens.

	All		Kept Russian		Not Kept Russian	
	Mean	Obs.	Mean	Obs.	Mean	Obs.
Russian queens help control Varroa mites better than other queens.	3.55	460	3.62	226	3.48	234
Difference (t-test statistic)				0.14(1.48)		
Colonies with Russian queens are more difficult to manage than colonies with other queens.	3.34	443	3.12	244	3.61	199
Difference (t-test statistic)				0.49*** (4.27)		
Colonies with Russian queens survive the winter better than colonies with other queens.	3.38	377	3.34	215	3.42	162
Difference (t-test statistic)				0.08 (0.64)		
Colonies with Russian queens produce more honey than colonies of other queens.	2.37	360	2.36	208	2.39	152
Difference (t-test statistic)				0.03 (0.30)		

Likert-scale: 1=Strongly disagree, 5=Strongly agree.
Responses of "Don't Know" are excluded.
*** denotes significance at the 1% level.