Factors Influencing Adoption of VSH Queens in the Honey Bee Breeding Industry

Julie S. Leiby
Graduate Research Assistant
Department of Agricultural Economics
Louisiana State University
Baton Rouge LA 70803
Email: jleiby1@lsu.edu

John V. Westra
Associate Professor
Department of Agricultural Economics
Louisiana State University Agricultural Center
Baton Rouge LA 70803
Email: jwestra@lsu.edu

Selected Paper prepared for presentation at the 2014 Southern Agricultural Economics Association (SAEA) Annual Meeting, Dallas, TX, February 1-4, 2014

Factors Influencing Adoption of VSH Queens in the Honey Bee Breeding Industry

Abstract

The Varroa mite is a threat to honey bees and beekeepers across the U.S. and is suspected to be one contributor to colony collapse disorder (CCD). In 2006, Varroa Sensitive Hygiene (VSH) bees were developed in response to this problem in the beekeeping industry. The hygienic behavior of VSH bees helps reduce susceptibility of colonies to Varroa mites, results in stronger colonies and decrease susceptibility to CCD. The objective of this paper is to identify factors that significantly influence the adoption of VSH technology. A probit model is used to identify factors these factors. Results indicate risk aversion, education and income significantly influence adoption decision.

Key Words: probit, queen honey bees, technology adoption, Varroa Sensitive Hygiene, VSH

JEL Classifications: R51, R58, O21, O23, R11, R38

INTRODUCTION

The *Varroa destructor* is a parasitic mite that has been a challenge for honey bees and beekeepers for the last few decades in the United States (Rinderer, 2010). USDA Census of Agriculture data from 1987 indicates significant departures from the beekeeping industry through 2002. Like many insect pests, the *Varroa* mite spread throughout the United States accidentally (Rinderer, 2010). It did not become widespread in North America until the 1980s, contributing to weakening bees' immune systems and assisting in the transmission of viruses to brood and adult bees (vanEngelsdorp, 2009).

Nearly the size of a pinhead, once a female Varroa mite attaches herself to a honey bee and eventually enters the hive, she finds a brood cell and lays multiple eggs on the pupae. The pupae soon develop with the new mites still attached (Harbo and Harris, 2009). The mites feed off of the bee's hemolymph, similar to that of human blood, slowly weakening the pupae until varroatosis incurs, a disease that results from the wound which can lead to death from infection. Because of physical, functional and behavior abnormalities, the colony is severely weakened with the remaining hive struggling to survive. The Varroa mite is considered to be the one of the leading causes of parasitic infestation of honey bee colonies across the United States (Danka, 2013).

Honey bees produced about 147 million pounds of honey in 2012 with a production value at just under $287 million (USDA-NASS, 2012). The varieties of crops pollinated by bees include almonds, apples, melons, alfalfa seed, plum, avocado, blueberry, cherry and many more (Morse et al., 2000). The importance of the severity of the damage the Varroa mite causes must be taken seriously, not just for the honey industry but also for the pollination of these important crops. The value of pollination services remains an essential output in the agricultural sector (Danka, 2013).

A variety of measures have focused on preventing this destructive mite. Some include non-chemical treatments such as the removal of capped drone brood, screened floors and sticky traps on the bottom board which are a form of mite trapping.

Chemical treatments such as fluvalinate and coumaphos have also been relied upon to protect honey bees and their colonies from the parasitic mite (Rinderer, 2010). Haarmann et al. (2002) conducted research on potential impacts of fluvalinate and coumaphos on honey bee queen health and found queens treated with coumaphos suffered a high mortality rate, sub-lethal effects such as physical abnormalities and observed atypical behavior. Their constant use has unfortunately led to the mites developing resistance to these chemical treatments (Elzen et al. 1999).

One alternative measure is the use of Varroa Sensitive Hygiene (VSH) bees. Because VSH bees require substantially fewer acaricide treatments and retain the commercial characteristics that beekeepers desire, breeding for this specific hygienic trait has been a goal for many researchers. VSH was developed at the USDA-ARS Honey Bee Breeding, Genetics and Physiology Laboratory in Baton Rouge, Louisiana. These researchers had imported a certain strain of bees from the eastern portion of Russia because of their coexistence with *Apis cerana*, a species of honey bee that have been exposed to the Varroa mite for a greater number of generations. VSH bees clean the bee hives of infected pupae and associated Varroa mites. These VSH queens began to be released to commercial queen breeders and producers in 2001.

For those beekeepers who have adopted this technology, Varroa mite levels have decreased dramatically in their colonies (Danka, 2013). However, since the release of VSH honey bees for beekeepers, the wide-spread adoption of VSH technology has not occurred. This raises a question for researchers - why have more beekeepers not adopted this technology? For those who have adopted VSH technology, what characteristics or traits are associated with them? If the characteristics or factors positively or negatively influence the decision to use this technology are known, extension or outreach efforts may be better developed and tailored to increase adoption of this technology and therefore effectively managing the Varroa mites challenge.

DATA AND METHODOLOGY

Following Dillman's (2000) Tailored Design Method for constructing and implementing surveys, a questionnaire was sent to survey commercial queen breeders across the United States. The list of queen breeders who received the survey was derived from beekeepers and queen breeders that either had purchased breeder queens from a major producer of queen bees and/or had previously been associated with VSH queens. Names of queen breeders were obtained from the USDA, ARS Honey Bee Breeding, Genetic and Physiology Laboratory in Baton Rouge, Louisiana. These commercial queen breeders are firms that breed queens for honey bee production which are then sold either directly to beekeepers or to other firms that breed queens for resale to smaller, hobby beekeepers. Data from 108 respondents to the survey out of a sample of 228 queen breeders were gathered and analyzed. Of the 108 respondents, 50 reported using VSH technology.

The probit model is a functional relationship that is used to represent a nonlinear S-shaped relationship between the explanatory variables and the probability of the dependent variable (Hill, 2008). In the current study, a probit model will be used to determine an individual's discrete choice of adoption or non-adoption since it encompasses a more realistic assumption of human behavior in this type of choice context (Hill, 2008).

The theoretical model of VSH adoption is specified as a function of information sources *(I)*, risk preference *(R)*, farm size *(S)*, demographics *(D)*, and household income *(M)*:

$$(1) \qquad Y_i = VSH_i = f(I, R, S, D, M)$$

$$i = (0,1)$$

where VSH_1 is the adoption of VSH queens (1 if breeder adopts, 0 otherwise); R is the risk preference the breeder takes in investment decisions; I is the information available to the bee breeder such as being a member of a local beekeeping club or beekeeping related organization; S is the farm size which indicates the number of colonies per breeder, M is the household income; and D is the demographic characteristics of the breeder such as experience, age, education and primary residence of the bee breeder.

Variables: Adoption Decision Model

Table 1 illustrates all variables used in the adoption decision model. The dependent binary variable, VSHX, indicates whether or not the breeder adopts VSH queens with the question, "Do you breed or sell queens?"

The variable CLUB represents whether the queen breeder is a member of a local beekeeping club. Involvement with sources of knowledge such as clubs and related organizations are considered to significantly affect adoption (Caviglia and Kahn, 2001; Arellanes and Lee, 2003; Foster and Rosenzweig, 1995). It is hypothesized that participation in beekeeping clubs on a regular basis has a positive relationship on the likelihood of VSH adoption.

The risk preference, RISK, indicates how respondents characterize their beekeeping investment decisions whether risk averse or risk neutral or taking. Based on previous literature on risk and uncertainty, risk aversion is hypothesized to be negatively associated with technology adoption (Marra and Carlson, 2002; Hardaker et al., 2004).

One variable, COLONY, represents farm size or number of colonies kept by the respondent. Farm size is usually included in studies of adoption evaluation since larger farms may have the advantage of having access to more information sources (Marra and Carlson, 2002). Because of this association that the larger the farm size of the VSH queen breeder, it is hypothesized that they are more likely to adopt VSH technology.

Four variables represent farmer demographics: experience of breeding and selling queens commercially, EXPER, the location of residence of the queen breeder, SOUTH, age in years, AGE, and the level of education of the breeder, EDUC. There are some linkages between age and experience in previous studies (Nagubadi, et al., 1996; Agarwal, et al., 1999), including a study whose results suggest the age of the individual or length of tenure in the workforce has a negative association and/or are more susceptible to negative interference under changing conditions of technology innovation (Agarwal, et al., 1999). I hypothesize that age does not have a significant relationship due to the idea that mostly any person can start breeding queens at almost any age of their life. Experience in breeding queens, however, is hypothesized to have in a positive influence in the probability of VSH queen adoption.

It is hypothesized that a positive relationship exists between education level and adoption. Education has been shown to be positively associated with innovation in other studies (Ersado et al., 2004; Rogers and Shoemaker, 1971). Rogers (2003) describes a degree of communication by interpersonal channels which involve a face-to-face exchange between two or more individuals. The location variable, SOUTH, will help give more insight of the information of VSH queens travel across regions. It is expected that location of residence will be significantly and positively influenced on the adoption decision having originated in the south and possibly disseminating throughout the

US. The states chosen for the southern region were based upon the United States Census Bureau census map.

A higher household income allows one to consume more goods and services. In return, utility may increase with the level of income. Income also helps overcome capitals constraint or finance the purchase of an innovation (Feder, et al., 1985). It is hypothesized that higher household income will positively influence the probability of VSH technology adoption.

Although much literature exists on the Varroa mite, economic analysis of Varroa-resistant bees, specifically VSH bees, is sparse. One goal of the VSH bees is to provide beekeepers an alternative in the battle against Varroa mites. To assist in expanding the literature and economic analysis on VSH bees, certain factors are involved in the influence decision of VSH bee technology. To determine those factors, a basic probit model will be used as follows which express the probability *p* that *y* takes the value 1 to be:

$$p = P[Y = 1] = \Phi\ (x'\beta) + \varepsilon \qquad (2)$$

where $\Phi\ (x'\beta)$ is the probit function and ε is the error term, *Y* represents adoption (VSH_1) and *x*' represents a vector of variables influencing *Y*.

RESULTS AND DISCUSSION

The results of the probit model examining VSH adoption behavior are presented in Table 2. The results provide some insight into how variables play a role in influencing the adoption decision in VSH queens.

While personal characteristics such as farm experience (Agarwal, et al., 1999) and location of residency (Rogers, 2003) have been associated with adoption of agricultural technologies, these factors have been shown to be not associated with adoption of VSH queens in the analysis. Even though most respondents had three or less years of queen breeding experience, EXPER, it was not a significant influence in VSH adoption. This may suggest the span of time learning the skill of queen breeding may be not as long and tedious. Location of primary residence, SOUTH, resulted in no influence on the adoption decision. According to Rogers (2003), innovation tends to disseminate from the originating source of invention and travel along channels in the diffusion process in spreading new technologies. Since living in the southern states did not have an apparent effect on the adoption decision, this could suggest queen breeders could potentially be receiving technical information from outside sources such as the internet and magazine subscriptions.

The variable that represents sources of information, CLUB, did not exhibit a significant association with VSH adoption in the analysis. This may be due to information that is provided through local clubs or beekeeping organizations may not be a very successful way of the passing of information from one source to another. Age has revealed not to be a significant factor in VSH adoption. This may be due to the prospect that VSH technology can be successfully adopted regardless of the age of the queen breeder.

Risk aversion, RISK, has shown to be both significant and positive at the 0.10 level. This implies that if the queen breeder is risk averse, the more likely they are to adopt VSH technology. Sometimes risk aversion may cause the farmer to become hesitant about adopting a new technology, especially if they are relatively comfortable with the status quo in their current farming situation. Since the results show that queen breeders tend to adopt if they are risk averse, this may be due to the severity of the Varroa mite destruction and how the queen breeders may be more determined to lessen the risk in their beekeeping related business and production.

The variable that controls for education, EDUC, has a positive and significance influence in the analysis. Most (84%) of the respondents have at least some college education or higher which coincides with the results in the current study. A higher education is an influential factor in utilizing VSH technology in their queen breeding business.

Farm size, COLONY, has shown to have no significance in influencing the adoption decision of VSH queens. This could possibly be due to the fact that bees are capable of travelling miles off-farm to find nectar and pollen for their hive. Therefore, a large plot land is not necessary to successfully host a colony of bees. Another reason may be from those who own a very large number of colonies may be comfortable with their method of production and feel no immediate need to adopt a new method, whereas those who own only a few colonies may be hobbyists or new to beekeeping or queen breeding and have yet to connect to the channels of information of VSH technology.

Household income, INCOME, has shown to be significant and negative at the 0.10 level. These results suggest that the higher category of household income, the less likely they are to adopt VSH queens. This might be due to a similar reason with farm size that queen breeders who have a higher household income may be satisfied with their current operation and feel no need to try new bee varieties. This also could suggest since higher household income could potentially mean higher profits, they could be more likely be better prepared for unforeseen circumstances.

Marginal Effects

Marginal effects for each variable are shown in Table 3 along with their respective standard errors, t-values and p-values. Three variables are statistically significant at the 10% level. These include if the queen breeders characterize themselves as risk averse, RISK, whether they hold a bachelor's degree or higher, EDUC, and their household income, INCOME. If the queen breeder is risk averse in their beekeeping investment decisions, the probability of adoption increases by 0.759. If the queen breeder holds at least a bachelor's degree, the probability of adoption increases by

0.748. For every $30,000 increment increase in household income, the probability of adoption decreases by 0.259.

CONCLUSIONS

Today, beekeepers are growing even more concerned about the health of their bee colonies. The increased presence of the Varroa mite has been a threat to colony and beekeepers where proper pest control and management has not been implemented. The damage of the Varroa mite has been one of the top concerns of beekeepers across the U.S. since its discovery in the 1980's. Since then, few remedies have been offered to help restore and maintain colony health. VSH has been considered to be an environmentally friendly and sustainable beekeeping management alternative that can help re-establish our pollinating bee population.

After a probit model was used to analyze the data, three variables were found to be significant and influenced the adoption decision. The results suggest having an adverse attitude toward risk in investment decisions promotes participation in VSH adoption. While having fears of the severity of the Varroa mite problem, queen breeders might be more aware of the benefits of VSH queens rather than risking alternative measures in their beekeeping related business. Those holding a bachelor's degree or higher may be more willing to adopt a new technology such as VSH. Finally, household income has shown to have a negative significance on the adoption decision where the higher increment of household income, the less likely they are to adopt VSH queens.

One of the limitations of this study is sample size. This could have included a wider range of queen breeders in the U.S. This also could be improved by expanding the scope of purchasers to include more than one list. This in return could potentially prevent possible generalizations to be made about the entire population of queen breeders from the smaller group of data that was collected.

These discoveries will benefit the beekeeping industry because industry leaders can help better inform queen breeders and beekeepers about the benefits of VSH technology, given these positive and negative factors associate with technology adoption. Extension and outreach efforts can be tailored and targeted to club meetings, online reports, field days, and demonstrations with an emphasis on the potential effect of VSH on reducing the risk of CCD and economic damages associated with Varroa mites. Such an appeal to risk-averse, better educated queen breeders and beekeepers may be more effective, given our improved understanding of the factors influencing adoption of VSH queens that resulted from this research.

REFERENCES

Agarwal, R., and J. Prasad. "Are individual differences germane to the acceptance of new information technologies?" *Decision Sciences* 30.2 (1999): 361-391.

Arellanes, P., and D.R. Lee. "The Determinants of Adoption of Sustainable Agriculture Technologies: Evidence from the Hillsides of Honduras." Paper presented at XXV Conference of International Association of Agricultural Economists, Durban, South Africa, August 2003.

Caviglia, J.L., and J.R. Kahn. "Diffusion of Sustainable Agriculture in the Brazilian Rain Forest: A Discrete Choice Analysis." *Economic Development and Cultural Change* 49(2001): 311–33.

Danka, R. G., T. E. Rinderer, M. Spivak, and J. Kefuss. "Comments on Varroa destructor: research avenues toward sustainable control." *Journal of Apicultural Research* 52(2): 69-71 (2013).

Danka, R. G., Research Entomologist, USDA, ARS Honey Bee Breeding, Genetics and Physiology Laboratory, May 2013, Baton Rouge, La.

Dillman, D. A. *Mail and Internet Surveys: The Tailored Design Method.* Vol. 2. New York: Wiley, 2000.

Elzen, P. J., J.R. Baxter, M. Spivak, and W.I. Wilson. "Control of Varroa jacobsoni Oud. resistant to fluvalinate and amitraz using coumaphos." *Apidologie* 31.3 (2000): 437-442.

Ersado, L., G. Amacher, and J. Alwang. "Productivity and land enhancing technologies in northern Ethiopia: Health, public investments, and sequential adoption." *American Journal of Agricultural Economics* 86.2 (2004): 321-331.

Fausti, S. W., and J. M. Gillespie. "A Comparative Analysis of Risk Preference Elicitation Procedures Using Mail Survey Results." *Annual Meetings of the Western Agricultural Economics Association*, Vancouver, British Columbia. 2000.

Feder, G., R. E. Just, and D. Zilberman. "Adoption of agricultural innovations in developing countries: A survey." *Economic Development and Cultural Change* 33.2 (1985): 255-298.

Foster, A., and M. Rosenzweig. "Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture." *Journal of Political Economy* 103 (1995):1176–209.

Haarmann, T., M. Spivak, D. Weaver, B. Weaver, and T. Glenn. "Effects of fluvalinate and coumaphos on queen honey bees (Hymenoptera: Apidae) in two commercial queen rearing operations." *Journal of Economic Entomology* 95.1 (2002): 28-35.

Harbo, J. R. and J. W. Harris. Responses to Varroa by honey bees with different levels of Varroa Sensitive Hygiene. *Journal of Apicultural Research*. 48 (2009): 156-161.

Hardaker, J.B. *Coping with Risk in Agriculture*, 2nd edn. CAB International, Wallingford. 2004.

Hill, R. C., W. E. Griffiths, and G. C. Lim. *Principles of Econometrics*. Vol. 5. Hoboken, NJ: Wiley, 2008.

Marra, M.C., and G.A. Carlson. "Agricultural Technology and Risk, Chapter 15." *The Role of Risk in Agriculture*. R. Just and R. Pope, eds. Norwell, MA: Kluwer Academic Publications, 2002.

Morse, R. A., and N. W. Calderone. "The value of honey bees as pollinators of US crops in 2000." *Bee Culture* 128.3 (2000): 1-15.

Nagubadi, V., K. T. McNamara, W. L. Hoover, and W. L. Mills, Jr. "Program participation behavior of nonindustrial forest landowners: a probit analysis." *Journal of Agricultural and Applied Economics* 28 (1996): 323-336.

Rinderer, T. E., J. W. Harris, G. J. Hunt, L. I. de Guzman. "Breeding for resistance to Varroa destructor in North America." *Apidologie* 41.3 (2010): 409-424.

Rogers, E. M. *Diffusion of Innovations*. Simon and Schuster, 2003.

Rogers, E. M., and F. F. Shoemaker. "Communication of Innovations; A Cross-Cultural Approach." (1971).

United States Census of Agriculture. 2007, 2002, 1997, 1992, 1987. *United States Summary and State Data: Volume 1, Geographic Area Series Part 51*. Table 60. Summary by Age and Primary Occupation of Principal Operator: 2007. U.S. Department of Agriculture, National Agricultural Statistic Service. United States Department of Agriculture.

USDA Economics, Statistics and Market Information System. 1976-2012. *Honey*. Albert R. Mann Library, Cornell University. Accessed August 2013. National Agricultural Statistics Service.

vanEngelsdorp, D., J. D. Evans, C. Saegerman, C. Mullin, E. Haubruge, B. K. Nguyen, M. Frazier, J. Frazier, D. Cox-Foster, Y. Chen, R. Underwood, D. R. Tarpy, and J. S. Pettis. "Colony Collapse Disorder: A Descriptive Study." *PloS One* 4.8 (2009): e6481.

Table 1. Description of the variables and definitions used in the analysis.

Variable	Description
Dependent	
VSHX	1 if respondent adopted VSH queen bees in 2012; 0 if otherwise
Independent	
Information Available	
CLUB	1 if respondent is a member of a local club or organization; 0 if otherwise
Risk Preference	
RISK	Relative to other investors, how would you characterize yourself? (Fausti and Gillespie, 2000). 1 if respondent characterizes themselves as risk averse; 0 if otherwise
Farm Size	
COLONY	Number of bee colonies respondent kept in 2012
Demographic Variables	
EXPER	1 if the years of experience of breeding or selling queens commercially was greater than 3 years; 0 if less than or equal to 3 years
SOUTH	1 if respondent's state of primary residence is located in the southern states: MD, DE, DC, WV, VA, NC, SC, WV, KY, GA, AL, MS, FL, LA, AR, OK, TX; 0 if otherwise
AGE	Respondent's age in years
EDUC	1 if respondent holds a bachelor's degree or higher; 0 if respondent has some college, technical school or less
Income	
INCOME	1 if respondent's household income was less than $30,000 in 2011, 2 if $30,000 to $59,999, 3 if $60,000 to $89,000, 4 if $90,000 to $119,000, 5 if $120,000 or greater

Table 2. Participation Behavior of VSH Adopters in the Analysis.

Variable	Estimate Coefficient	P-Value	Standard Error
INTERCEPT	1.2680	0.2048	1.0001
EXPER	0.2917	0.5038	0.4363
SOUTH	0.4554	0.2516	0.3972
CLUB	0.5161	0.1742	0.3798
AGE	-0.0228	0.1543	0.0160
RISK	0.7586	0.0666*	0.4135
EDUC	0.7479	0.0795*	0.4264
COLONY	0.0000	0.7736	0.0001
INCOME	-0.2588	0.0805*	0.1481
Log Likelihood function:	-31.834		
Percent Concordant:	78.7%		
Total R-Square:	0.199	Adjusted R-Square:	0.078
Number of Observations:	62		

*Significance at the 10% level

Table 3. Marginal Effects

Variable	Estimate	Standard Error	t-Value	P-Value
Intercept	1.268	1.000	1.27	0.204
EXPER	0.292	0.436	0.67	0.504
SOUTH	0.455	0.397	1.15	0.251
CLUB	0.516	0.380	1.36	0.174
AGE	-0.023	0.016	-1.42	0.154
RISK	0.759	0.414	1.83	0.067*
EDUC	0.748	0.426	1.75	0.080*
COLONY	0.000	0.000	0.29	0.774
INCOME	-0.259	0.148	-1.75	0.081*

*Significance at the 10% level.