2014

Factors influencing adoption of VSH queens in the honey breeding industry

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FACTORS INFLUENCING ADOPTION OF VSH QUEENS IN THE HONEY BEE BREEDING INDUSTRY

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Agricultural Economics and Agribusiness

by
Julie Leiby
B.A., Moravian College, 2005
May 2014

ACKNOWLEDGEMENTS

I would like to express enormous gratitude to my graduate committee, Dr. Rich Kazmierczak and Dr. Jeff Gillespie for their endless, unconditional and caring support, as well as my advisor, Dr. John Westra, for his guidance. I couldn't think of a better group of individuals with the knowledge and proficiency I needed to help guide me through this experience. Along with this group of individuals I would like to include the other faculty members of the Agricultural Economics, Environmental & Sciences and Economics departments which include Dr. Carter Hill for his unconditional and caring support, Dr. Krishna Paudel, Dr. Richard Stahl, Dr. Walter Keithly, Dr. Michael Salassi, Dr. Margaret Reams, and Dr. David Brown for their teachings and knowledge. Dr. Mike Batech deserves very special gratitude and appreciation for his statistical expertise and knowledge, as well as his caring assistance. I would also like to thank Marla Spivak and Malcolm Sanford for their help in my understanding of certain bee strains and their behavior in the hive. They are an endless resource of information on bees. Another individual that deserves my gratitude is Dr. Bob Danka of the USDA-ARS Honey Bee Breeding, Genetics and Physiology Laboratory here in Baton Rouge. He has selflessly provided me not only with an opportunity to research a topic that I have been interested since I was a little girl when my dad kept and raised his own bees, but also the insightful and in-depth knowledge of the tiny little pollinators that we have most recently realized to be increasingly important in today's agricultural based society. Thank you, Bob, for I will continue to take my love for bees far beyond the horizon of graduate school.

I would also like to thank the numerous graduate students, most notably Michelle Savolainen, Kayla Brown, Luke Boutwell, Rebekah Powell, Jordan Newell, Aude Liliana Maradiaga-Pujula, David Maradiaga, Jeremy D'Antoni, Issac Sitienei, Muditha Nanayakkara, Deborah Williams, Jill Christoferson, Narayan Nyaupane, Aditya Khanal, Elizabeth Jenkins, Bo Lin, Natalia Latorre, and others, who have helped me along the way, even in the most minute way, during my classes and thesis-writing.

Lastly, I would like to express my gratitude and love for the most important beings in my life: my parents, David and Sharon, my two sisters, Sarah and Caroline, my “mini-sister” Lena, my husband, Patrick, and my fur-child, Milo, for their support, love and smiles throughout this entire experience. I would not be the person I am today without your positive and uplifting influence. Much love to you and thank you so much.

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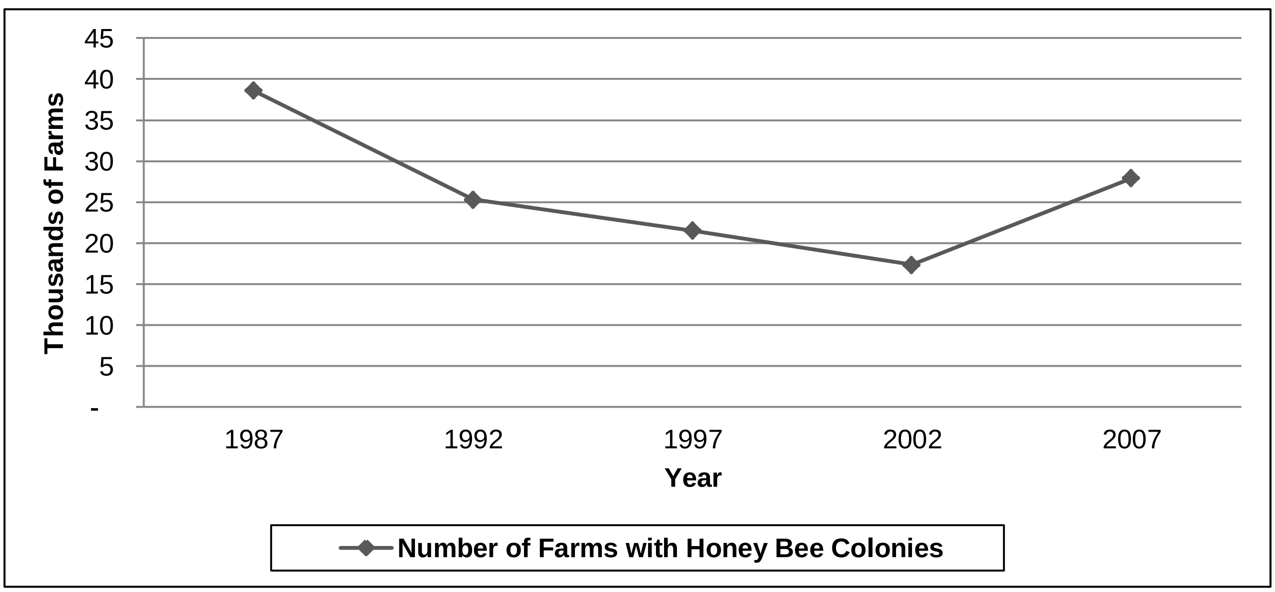
ABSTRACT

There are many threats that contribute to the decline in honey bee colonies around the United States; among them is the Varroa mite, *Varroa destructor*. The Varroa mite is a significant threat to honey bees and, by extension, beekeepers across the United States. It is suspected to be one of the main contributors to the increase in colony collapse and the decline in bee numbers and the beekeeping industry (Danka, May 2013). Fifty-five percent of beekeepers exited beekeeping between 1987 and 2002 (USDA). Although honey production continued to decrease through 2007, the number of beekeepers entering beekeeping had increased (USDA). In 2006, the Varroa Sensitive Hygiene (VSH) genetic line of bees was developed in response to the destruction associated with the Varroa mite. The hygienic behavior of this line of bees helps reduce susceptibility of colonies to Varroa mites and results in stronger colonies with increasing bee populations (Rinderer, 2010). Relatively little information exists on the adoption level of VSH technology in the beekeeping community and beekeeper’s perceptions of VSH technology. The objective of this study is to identify and discuss factors that significantly influence the decision of adopting VSH technology. Using data collected from a sample of 228 queen breeders across the United States that previously adopted other Varroa sensitive technologies, a probit model is used to analyze the factors involved in influencing the adoption of VSH queens by queen breeders. Factors analyzed include sources of information available, risk preference, sales attributes, demographic information, and income. Results indicate that education level, being risk averse and income all had a significant influence on the adoption decision.

CHAPTER 1. INTRODUCTION

1.1. Background and Problem Definition

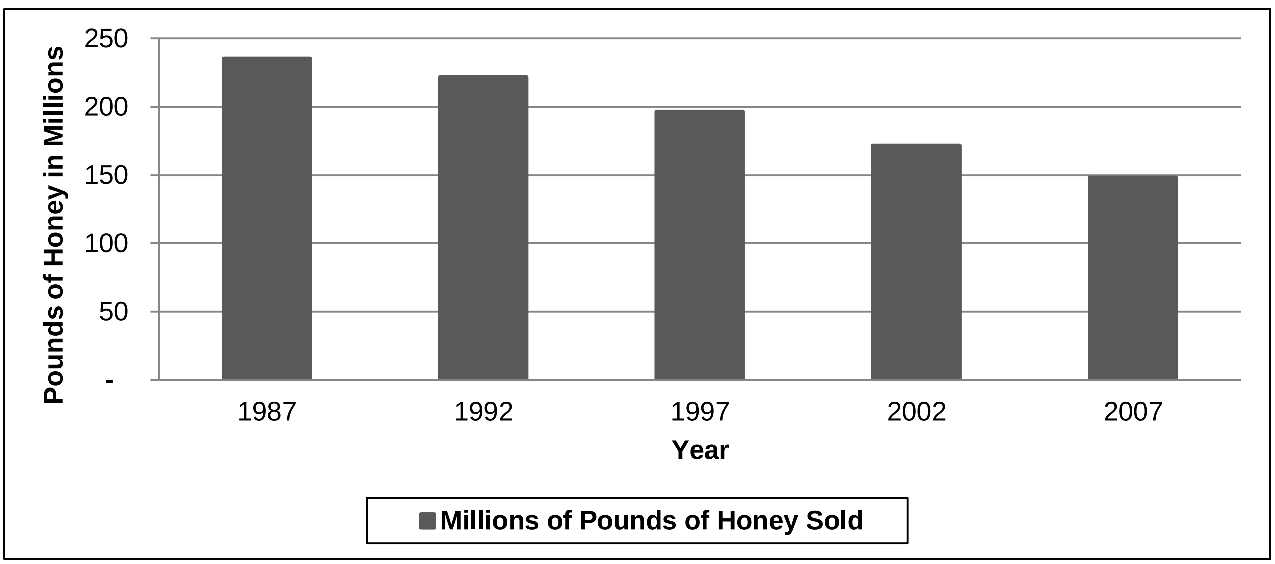
Beekeepers in the United States have been battling the parasitic mite *Varroa destructor* for decades (Rinderer, 2010). It poses a significant challenge to beekeepers, with the infestation of honey bee colonies contributing to a significant decline in the beekeeping industry (Danka, 2013). If infestation becomes severe and detrimental to colony health, producers spend much effort in rebuilding colonies instead of using that potentially lost time and effort for growing and producing goods and profit. If this scenario continues for extended periods of time, bee keepers may end up sustaining economic losses and could possibly exit the beekeeping industry. USDA Census of Agriculture data from 1987 indicates significant departures from the beekeeping industry through 2002. Fifty-five percent of the farms with bee colonies resigned from keeping bees between 1987 and 2002 (Figure 1.1) (USDA-NASS, 2013) although there was a recent increase from 2002-2007.



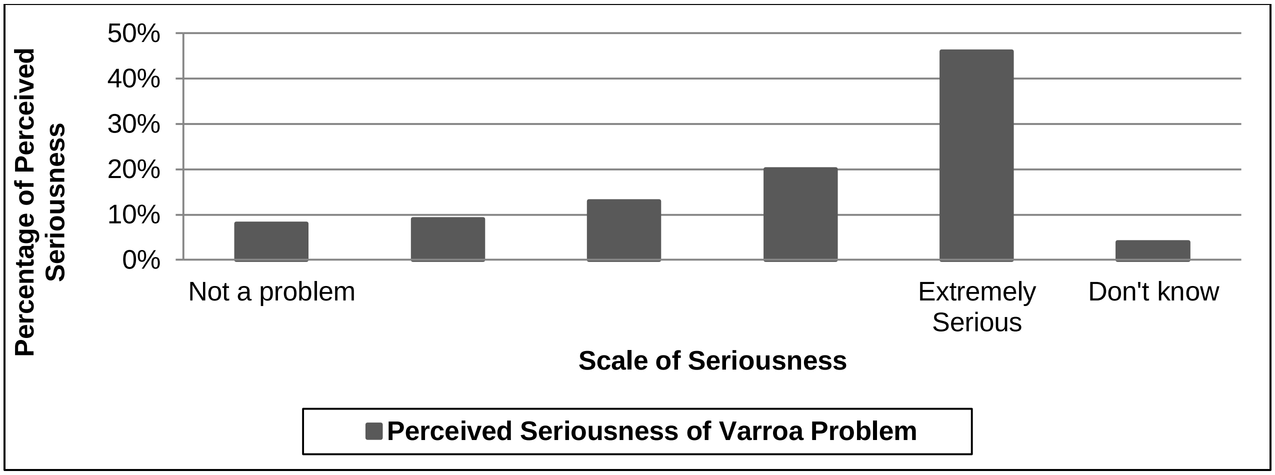
Source: USDA/NASS, 2013
Figure 1.1. Total U.S. Farms with Honey Bee Colonies, 1987-2007

This decline in farm numbers was accompanied by a 17% reduction in the number of bee colonies in 2002 and a 37% reduction in honey production through 2007 (Figure 1.2) (USDA-NASS, 2013).

In a study by Kim et al. (2006), two-thirds of beekeepers indicated Varroa mites were a “very serious” or “extremely serious” problem in their operation; almost one-half (46%) indicated it was “extremely serious” (Figure 1.3). Total colonies lost to Varroa mites, as reported by responding beekeepers in Kim et al. (2006), had nearly doubled from 174,000 colonies in 2001 to 342,000 colonies by 2004 (Figure 1.4). Recent advances in bee breeding and Varroa mite control methods, among other developments, have contributed to the beginning of a recovery of beekeeping the industry, as seen by the increase in the number of farms with honey bees in 2007. Until recently, beekeepers’ options for controlling Varroa mites were limited to certain chemicals – the acaricides, fluvalinate and coumaphos. The future effectiveness of these products remains uncertain because

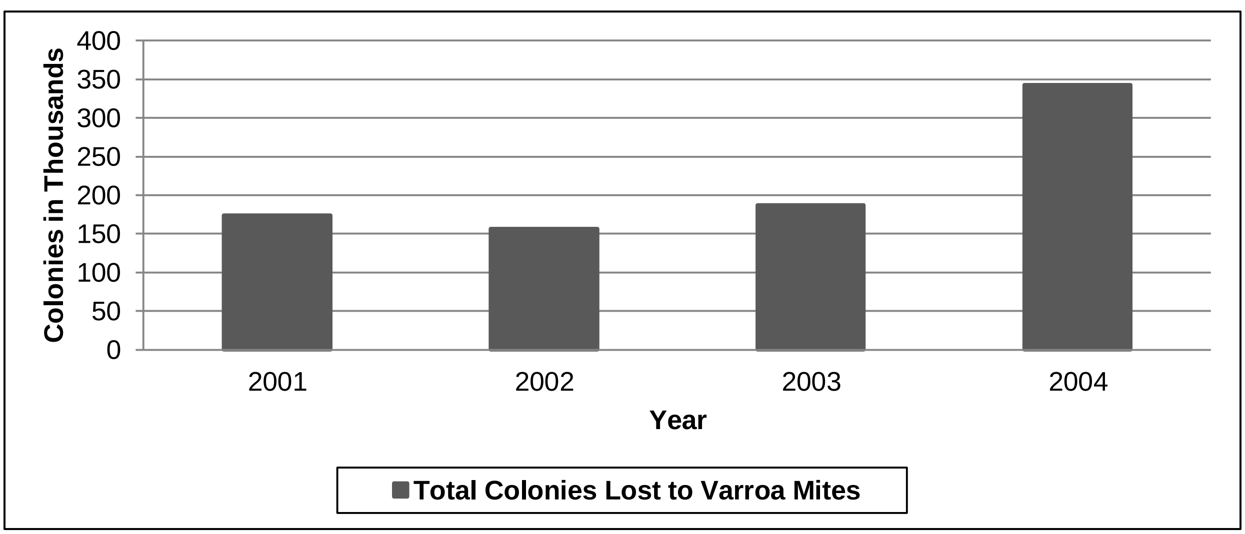


Source: USDA/NASS, 2013
Figure 1.2. Total Pounds of Honey Sold in the U.S., 1987-2007



Source: Kim et al, 2006
Figure 1.3. Perceived Seriousness of the Varroa Mite Problem, US Honeybee Producers

Varroa mites appear to be developing resistance to these chemicals in certain areas of the country (Danka, 2013). Queens from a line of Varroa Sensitive Hygiene (VSH) honey bees, selected for hygienic behavior traits with Varroa mites by researchers at the USDA Agricultural Research Service (ARS), began to be released to commercial queen breeders and producers in 2001 (Danka, 2008). Because infestation of Varroa mites can weaken or decimate a honey bee colony, producers



Source: Kim et al, 2006
Figure 1.4 Total Colonies Lost to Varroa Mites

have been seeking economical means for controlling them. It has been a little over a decade since VSH queens have been commercially available in the beekeeping community. Beekeepers have been adopting this technology with results of decreasing levels of mite growth (Danka, 2013 and Danka, May 2013).

1.2. Research Question and Objective

Since the release of VSH honey bees for beekeepers, information on adoption levels have been sparse. However, a study conducted in 2005 reported that Varroa-resistant Russian honey bees were being used by only 24% of US beekeepers (Kim et al., 2006). The primary objective of this research is to identify those factors influencing adoption levels of VSH technology. Past literature identifies some common factors that are associated with increased or decreased likelihood of adopting new technology. Factors identified usually include access to relevant information about the technology, uncertainty and aversion to risk, as well as education, age, income and other related demographic characteristics. This thesis reviews studies that are relevant to technology adoption, risk preference, and uncertainty pertaining to adoption of innovations as well as pest resistance and control.

1.3. Arrangement of Thesis

The layout and arrangement of the thesis is as follows. Chapter 2 discusses background information necessary to understand the severity of *Varroa destructor*, a review of relevant literature regarding technology adoption, adoption of similar pest resistance, and control methods, as well as technology adoption regarding risk preference and uncertainty. Chapter 3 includes a description of how the data was collected, a discussion of variables used in the model, details of the conceptual model used, and the analysis methods. Chapter 4 provides the probit results, and the marginal effects along with a discussion of their implications. Lastly, Chapter 5 presents a summary, conclusion and the limitations of the study.

CHAPTER 2. LITERATURE REVIEW

A rich volume of literature exists for the adoption of new technology. Relevant topics in this study include technologies related to pest and disease control, honey bee technologies, and technology adoption topics related to risk aversion and uncertainty toward the adoption decision of the farmer.

2.1. The *Varroa destructor* and Breeding for Resistance

The *Varroa destructor*, as its name foretells, is a parasitic mite that has been a challenge for honey bee colonies and beekeepers for the last few decades in the United States (Rinderer, 2010). Like many insect pests such as the Small Hive Beetle (*Aethina tumida*) which was introduced through Florida (de Guzman, 2010) and the Tracheal Mite (*Acarapis woodi*) which was first discovered in the United States in 1984 (Delfinado-Baker, 1984), the Varroa mite spread throughout the United States accidentally (Rinderer, 2010). Nearly the size of a pinhead, the Varroa mite 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 et al., 2009).

Once a female 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, 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. De Assis Pinto et al. (2011) and Rosenkranz (2010) indicated that if the Varroa infestation is severe, the colony’s health is severely impacted. According to the National Agricultural Statistics Service the number of honey bee colonies has substantially declined (USDA-NASS, 2013) since the discovery of the *Varroa destructor* in the United States in 1986. Additionally, remaining surviving colonies have been shipped to many farms across the United States to pollinate crops, which can result in stress, confusion, and narrowing of dietary needs (Danka, 1987). 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).

The honey bee has completely changed American apiculture's history of 400 years of existence from when the colonists first brought them to the New World in the 17th century (Doebler, 2000). Honey bees produced about 147 million pounds of honey in 2012 with a production value at just under $287 million (USDA-NASS, 2013). The varieties of crops pollinated by bees include almonds, apples, melons, alfalfa seed, plum, avocado, blueberry, cherry and many more (Morse et al., 2000). Morse et al. (2000) further argues that the value of honey bee pollination of wild fruit, nuts and seeds is unknown yet obviously substantial. Just in California alone, more colonies of honey bees are owned and operated than in any other state, while almond production pollination has used more colonies than any other single crop (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).

Beekeepers have focused on a variety of measures to help prevent this destructive mite from causing devastation to beehives. Some of these measures include non-chemical treatments such as the removal of capped drone brood, screened floors and sticky traps on the bottom board. Sticky traps are an alternate form of trapping mites. Chapleau (2003) found that a screened bottom board had succeeded in reducing the Varroa population by 37% during the 2001 pollinating season.

Charriere et al. (2003) found the removal of drone brood impedes the development of Varroa mite populations.

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 the two chemicals weighed significantly less than the low-dose or control queens. It was only the queens treated with coumaphos that suffered a high mortality rate, with sub-lethal effects such as physical abnormalities and atypical behavior were observed in the same group of queens.

While chemical treatments have been used to treat infestations, their constant use has unfortunately led to the mites developing resistance to these chemical treatments. For example, Elzen et al. (1999) conducted laboratory tests investigating the effects of fluvalinate and coumaphos on mites infesting honey bee colonies. They found the mites were resistant to fluvalinate, but coumaphos was relatively effective against the resistant mites. Haarmann et al. (2002) found coumaphos to be more toxic to honey bees than fluvalinate, while Pettis et al. (2004) studied the effects of coumaphos in beeswax on queen production. They found larvae that were exposed at higher doses of coumaphos did not develop at all and only 50% of the larvae developed at lower doses. Those that survived the low dose exposure weighed significantly less than control queens. This resistance and increased use of chemicals for parasitic mite control, combined with problems beekeepers face associated with maintaining productive queens in their colonies, is causing beekeepers and bee breeders to seek out alternative mite control measures in their beekeeping business (Sanford, 2001).

One alternative and important measure that has been developed is the use of Varroa-resistant honey bees. Because Varroa-resistant honey 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. Three primary breeds have been developed within North America. The Minnesota Hygienic stock has produced substantial Varroa resistance (Spivak et al., 2009) as well as the Russian Honey Bee (RHB) (Harris and Rinderer, 2004) and the Varroa-Sensitive Hygiene (VSH) honey bee (Ibrahim et al., 2007). The latter two lines of bees were both 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. This species of honey bee has shown to be more than twice as tolerant of the mite as other bee lines sold commercially (Ambrose, 2000). Although RHB and VSH bees differ in general breeding approach, they were both specifically developed for suitable commercial use.

The current study focuses mainly on VSH technology and factors involving its adoption from queen breeders in the United States. Figure 2.1 illustrates a timeline of the number of colonies owned and maintained across the United States in millions. It is around the time of the sharp drop in colonies in 1986 when Varroa mites were first discovered in the United States. It was not until a decade later in 1996 when VSH bees were introduced into the beekeeping industry for commercial and private use. At this time, it was about when the number of colonies started to level off and stabilize according to the presented data. As a result, the introduction of VSH may have possibly contributed to the stabilization of colonies and prevented them from decreasing in number any further.

Source: USDA/NASS, 2013
Figure 2.1. Number of Colonies Existing in the U.S., 1976-2012

Varroa Sensitive Hygiene (VSH) is a behavioral trait in which the honey bee locates infected pupae and removes them from the colony while leaving the uninfected pupae untouched in their brood cells. In a study done in 2010 on a queen production industry in Hawaii, researchers found that 91% of the mite infested brood was removed from a VSH hive, compared to a 9% removal rate for a group of mite-susceptible bees (Danka et al., 2010). Although the progeny of the VSH queen will have less resistance to the Varroa destructor than the general population of bees that are 100% VSH, they will still be useful to the survival of the colony (Kim et al., 2006). In return, it has been shown that VSH yields a high level of sterile mites among the remaining colony (Harbo and Harris, 2009). Even though the details of how VSH bees detect mite infested brood cells are unknown, VSH bees allow beekeepers an alternative option to control the Varroa mites.

2.2. Technology Adoption

Technology adoption is one of the most extensively researched topics in agricultural economics. Many authors have revealed extremely important information about the technological change process (Griliches, 1957; Feder et al., 1985; Doss, 2006; Rogers, 2003). Nelson (1982) explains the framework of the innovation process by stating:

> We have for example, much evidence of the role of insight in the major invention process, and of significant differences in ability of inventors to "see things" that are not obvious to all who are looking. Yet once one has made a breakthrough, others may see how to do similar, perhaps even better, things. The same patterns apparently obtain in innovation.

This is a prime example of the first steps of the innovation process which will then potentially lead to technology adoption. Some technology may be accepted relatively well across the sample studied, where other technologies may be adopted by only a smaller group of farmers. A number of factors have been shown to influence the adoption behavior of farmers across socioeconomic groups. The purpose of this literature review section is to examine previous studies that have attempted to identify factors associated with increased or decreased probability of adoption.

Griliches (1957) was one of the earlier studies in technology adoption. He studied the aggregate economic behavior and the factors influencing adoption rates of hybrid seed corn use across areas and over time in the United States. His results showed the adoption behavior associated with hybrid corn followed an S-shaped curve. Other extensive reviews of technology adoption literature include Feder et al. (1985), who surveyed numerous studies that have attempted to explain adoption patterns in developing countries. They introduce a general conceptual framework for analyzing the adoption and diffusion processes and suggest new approaches for methods and models used in the empirical literature. To have a complete analytical framework for investigating adoption processes at the farm level, they argue the framework should include a model of the farmer's decision making and a description of patterns that describe the farmer's decisions. Some patterns noted include farm size, risk preference and uncertainty, human capital, labor availability, credit constraints, tenure arrangements and the proportion of farms rented on adoption technology, supply constraints and aggregate adoption over time. One last important topic raised is the well-know adoption "S" curve that has helped exemplify new technology adoption in agricultural environments.

Rogers (2003) continues with this idea and states that diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system. He defines innovation as being a technology that is perceived as something new and has not yet having a favorable or unfavorable attitude toward it. Communication channels are essential to the exchange of information by which one individual communicates an idea to others. Time is involved in diffusion, from which an idea is passed from first acknowledgement to adoption or rejection, as well as the rate at which the innovation is adopted. Social system is the last element of the diffusion process, where a set of interrelated units, such as members of a group or organizations, are engaged in solving a common problem to accomplish a mutual goal. When some innovations are perceived as risky and uncertain, many people tend to seek others who have had experience with the new technology.

The decision to adopt an innovation is a process that unfolds over time rather than being an instantaneous act (Rogers, 2003). Rogers presents a model that describes the innovation decision process that consists of five stages: knowledge, persuasion, decision, implementation, and confirmation. Knowledge consists of exposure to new information and understanding its use. Persuasion is when the new information gains acceptance among the potential adopters. Decision is when the knowledge is being used to decide upon the choice to adopt or reject the innovation. Implementation involves the actual use of the innovation, where confirmation is the reinforcement of the innovation decision. This hierarchy of effects model was first conceptualized by Ryan et al. (1943), revised by McGuire (1989), and is now being widely used (Rogers, 2003).

Feder (1980) described the coexistence of technology adoption and uncertainty. Although he focused on explaining conflicting evidence on certain patterns of output by different sized farms, he expanded on a model originally developed by Just and Pope (1978) to clarify the factors involved in the adoption decision. The model included two crops, one traditional crop with less uncertainty and one modern crop with more uncertainty, produced on the same farm and requiring decisions such as the optimal input of fertilizer, optimal allocation of land, implications of limited credit availability and income distribution effects involved in the adoption decision. He found that the decision is not affected as long as the traditional crop's mean yield response to chemicals and degree of yield uncertainty are both lower than that of the modern crop. In return, Feder (1980) argues the model can be applied to a variety of adoption decisions involving production uncertainty across different regions and farm sizes.

One of the main points presented was that the above aforementioned factors influencing adoption decisions were often interrelated. Farm size can have different effects on adoption depending on the characteristics of the technology such as fixed adoption costs and risk preferences. Often, fixed costs of implementation are an obstacle to adopting new technologies, as they affect adoption levels of smaller farms. Aversion to risk plays another important role in possibly hindering technology adoption. Exposure to relevant information through various sources is known to reduce uncertainty (Feder et al., 1985). Since measuring the extent of information the farmer is exposed to can be quite problematic, Feder et al. (1985) suggested using a proxy variable that represents different channels of information the farmer receives, such as whether the farmer was visited by extension services or whether he or she attended programs designed by the extension agency. They also surveyed previous literature of the effects of human capital and found that it is mostly positively related to adoption.

Another important study on technology adoption was conducted by Doss (2006) who analyzed the limitations and challenges of adoption microstudies in Africa. Microstudies focus on the study of small towns or villages, on single individuals or incidents that seem insignificant in themselves (de Chadarevian, 2009). Doss (2006) suggests alternative approaches for technology adoption studies so policy makers can find them more useful. She offers opportunities for improvement by emphasizing the importance of panel data which assesses the dynamics of adoption decisions over time. Cross-sectional data are important in gathering the basics of the sample studied, such as identify constraints to technology adoption and input use, but panel data allow researchers to better understand long-term effects of adoption. This allows for insight into the dynamics on a smaller scale within the bee breeder's adoption decision. Doss (2006) also emphasizes learning and social networks involved in technology and examined different studies whose results have shown a significant influence in adoption due to social learning, observations and experiences of neighbor's crop production, as well as the effects of social networking. These types of studies help us understand more aspects of the adoption process. Since networking is a very important aspect of our VSH honey bee study, I have incorporated questions that integrate that concept in the questionnaire administered to bee breeders.

Among the technology adoption literature relating to Varroa resistant trait is the research of Kim et al. (2006), who assessed the extent of Russian Varroa-resistant queen bee adoption in the beekeeping industry and also identified some of the factors affecting adoption. Among the factors assessed, they found that farm size does not significantly influence the adoption, commercial beekeepers adopt larger quantities of Russian Varroa-resistant bees, and higher household income negatively influences the likelihood of adoption. They also found that having a greater number of contacts with USDA increased the likelihood that beekeepers kept Russian bees. Lastly, membership with the American Beekeeping Federation (ABF) negatively affected Russian bee adoption, while membership with the American Honey Producers Association (AHPA) increased the probability of adoption.

2.3. Technology Adoption, Pest Resistance and Control

Over the years, pesticides have allowed farmers to increase their overall land productivity. From an economic perspective, pesticides have generated many benefits for society, such as lower production costs, higher yields and higher profits. Despite these economically positive effects, the Economic Research Service (ERS) (2012) reports that farmers spent just under $12 billion on pesticides in 2011, a 27% increase from ten years before. This increase in pesticide usage has caused a concern among human health officials (EPA). The Environmental Protection Agency (EPA) has been regulating pesticides since 1910 (EPA, 2012) and continues to regulate new pesticides before coming on the market. Fernandez-Cornejo et al. (1998) summarize empirical evidence related to the economic effects of pesticide use with an emphasis on the estimation of the value of pesticides in U.S. agriculture. They also study the economic effects of promoting alternative methods to manage pests.

Integrated pest management (IPM) is one way to manage pests, while at the same time reducing the potential negative health and environment consequences of pesticide use. Instead of eradicating the pests completely, IPM encompasses a number of techniques aimed at lessening the effect of pest infestation (Vandeman et al., 1994). One of the many techniques of IPM is insect control. Insect control may be defined as the use of insects to control themselves (Davidson, 1974). In the case of VSH queens, breeding for resistance offers a type of insect control in the assistance of controlling the varroa mite. Since the methods of genetic control are found to be species-specific and non-polluting, VSH queens allow beekeepers and queen breeders an alternative to insecticides and miticides.

An early example of successful genetic control involves the eradication of the cattle-killing screwworm (Knipling, 1955). Sterilization of the male adult fly resulted in insufficiently developed embryos (Klassen et al., 2005). This sterilization program of the screwworm helped prevent lost revenues for cattle farmers in North and Central America (Vargas-Teran et al., 2005). Sterilization also helped California and Florida combat introductions of the Medfly, which causes extensive damage to fruit crops (Hendrichs et al., 2002).

Since comprehensive studies of infection-control traits in social insect lineages tend to be sparse, Fefferman et al. (2007) studied the effectiveness of nest hygiene in the interactions of social insects such as ants and termites. They found factors such as allogrooming increased the survivorship of the colony, suggesting that infection control systems can serve as important determinants to manage exposure and transmission of disease. Similar hygienic behavior has been noted with Cape honey bees, European honey bees and the parasitic Small Hive Beetle. It has been shown that both Cape and European honey bees detect all infected brood and remove them from the hive (Ellis et al., 2006).

Carlson and Wetzstein (1993) believe pest management decision models are one of the primary inputs in developing recommendations to farmers on the quantities and types of pesticide management and other resources to use. Understanding of how beekeepers make pest management choices will help biological researchers develop specific pest control recommendations. There are many features of the pest damage abatement process that determine the influence of optimal farmer behavior and the genetic selection of VSH queen bees is a very important way to support pest control.

2.4. Technology Adoption, Risk Preference and Uncertainty

Among the extensive literature of technology adoption, Marra and Carlson (2002) discussed the impacts of risk on the technology adoption process. They note that a clear understanding of the potentially adopted technology is a significant factor in the actual adoption and diffusion process. This understanding consists of not only developing, disseminating and understanding the technology, but also implies an initial opportunity cost of actually adopting the new technology. Marra and Carlson (2002) describe empirical examples of agricultural settings in developed and developing countries involving risk and uncertainty in technology adoption decisions. Uncertainty may contain many layers of ambiguity, depending on the setting. Marra and Carlson (2002) argue that having analytical perceptions of risk and risk aversion may help clarify uncertainty in certain adoption models. Lastly, Marra and Carlson (2002) suggest larger farms may have an advantage over small farms in accessing knowledge, and reducing uncertainties.

Uncertainty can come in many forms when considering adoption. The diffusion of a technology may appear as a slow and continuous process. To understand why it may be slow at times, we must examine how technological change comes about. One important aspect that deserves is the understanding of the choice between adopting now or deferring the decision to a later time (Hall et al., 2003). The reason for this is the way we observe the nature of costs and benefits. For example, the benefits from adopting a new technology are received throughout its entire span of use and thus the costs may not be recovered quickly.

Profitability is another concern that coincides with uncertainty among farmers when considering adopting a new technology. One question that may arise in this situation is whether adopting VSH queens is more profitable in the long run compared to the status quo? In an ideal economic setting, adoption of VSH queens would result in a higher profit in the long run while minimizing costs and frustrations caused by the Varroa mite. This is an important question to keep in mind throughout my research.

Another important study on risk preference and uncertainty was conducted by Hardaker et al., (2004) who analyzed the influence of the decision maker's attitude to risk in both profit and utility maximizing situations. Hardaker et al. (2004) defines uncertainty as imperfect knowledge and risk is defined as uncertain consequences. For example, when someone is uncertain of the weather conditions for tomorrow, they are demonstrating imperfect knowledge of the future. But that person may have planned an outdoor activity in the future, despite the possibility of unfavorable weather, a risky action taken with uncertain consequences in the future. Within the context of VSH technology adoption, there may be a great deal of uncertainty of the outcome. Examples include possible initial fixed costs, unknown time and cost constraints of learning the technology, as well as other factors that may determine uncertainty such as the relationship between adoption and farm size, human capital, credit constraints, labor necessities, and tenure planning.

Larson et al. (2002) argue the potential uses and implications of technology adoption in risk management. They discuss that variable rate technology (such as precision farming) may be helpful in reducing yearly variability in net returns. Precision farming technology can have other risk management benefits, such as reducing the risk of environmental and food contamination (Lowenberg-DeBoer et al., 1996). Larson et al. (2002) also discuss how some agricultural technologies may actually increase some types of risk such as the late adoption of precision farming that are unable to effectively use the technology are less likely to survive than early adopters (Cochrane, 1958). Roberts et al. (2000) have indicated that some precision farming technologies are more complex than traditional technologies when then require more time, skill and knowledge to fully adopt the technology. When farmers are uncertain about accepting a new technology or its impact, they may adopt only certain components of the innovation (Leathers et al., 1991) such as enrolling in a program which is funded by the service helping to diffuse the innovation. Lastly, Batte et al. (1990) found the perceptions of decision makers can possibly influence the adoption choice of using computers for farm management. Therefore, the perceptions of farmers can have a great influence on the adoption decision.

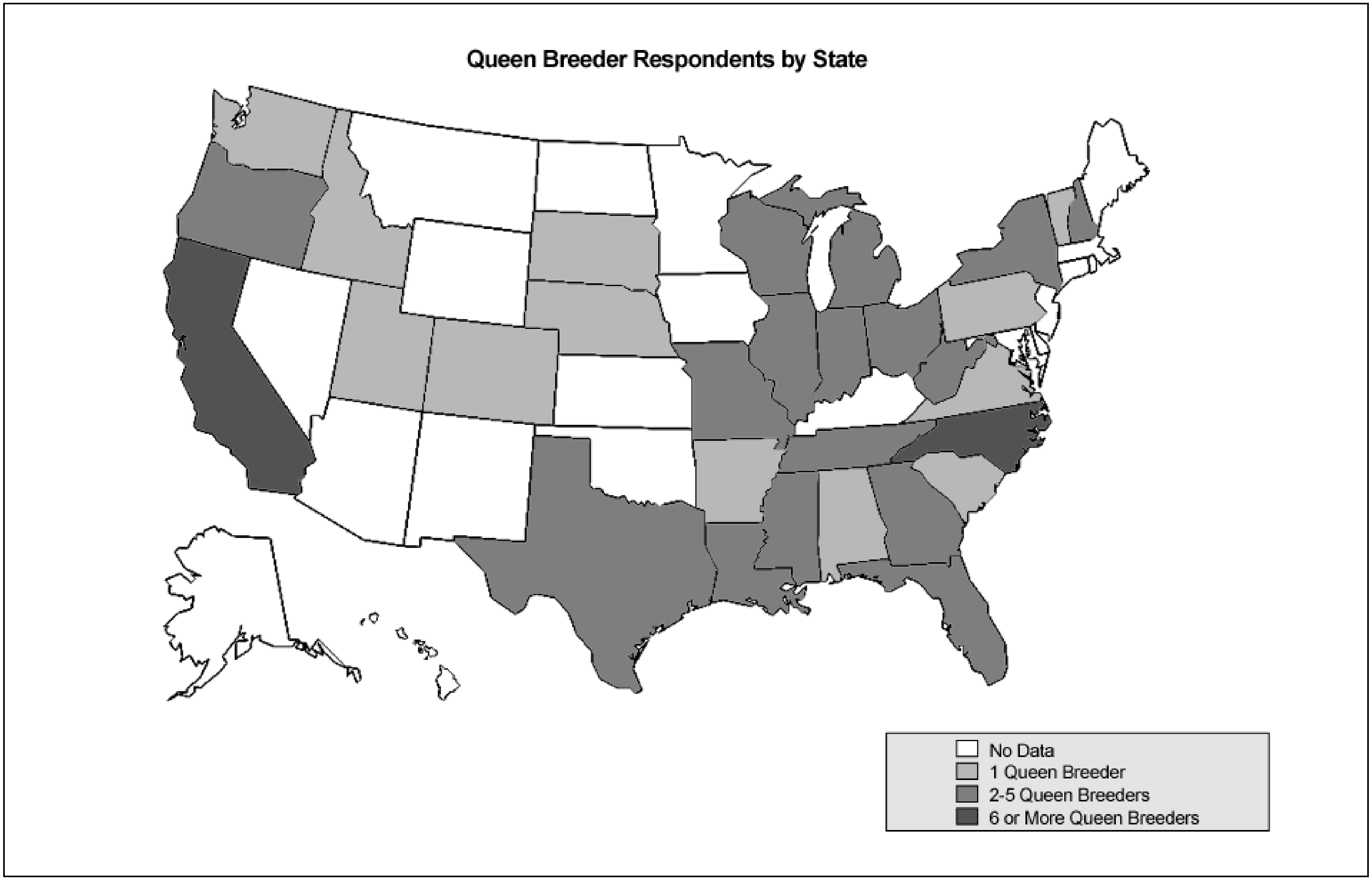
Depending on these decisions, risk preference may be a significant factor. Current literature suggests that most people tend to be risk averse and are willing to give up a potential return for a lesser degree of risk in certain situations (Radcliffe et al., 2009). We can find evidence of risk aversion in the decisions of farmers by observing their preferences in particular farming systems (Feder 1980; Binswanger et al., 1983).

CHAPTER 3. DATA AND METHODOLOGY

3.1. Survey Data

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. Consequently, the sample is not truly representative of the general queen breeding population, but of the group that previously adopted similar technologies. See the Appendix for the actual survey sent to the respondents. A map of respondents per state is given in Figure 3.1. Names of queen breeders were obtained from the USDA, ARS Honey Bee Breeding, Genetic and Physiology Laboratory in Baton Rouge, Louisiana.

Following Dillman's (2000) Tailored Design Method for constructing and implementing surveys, five contacts were made. A pre-notification letter was sent to the 228 queen breeders to notify that they would soon be receiving a queen bee breeding survey in the mail. A cover letter, survey and a self-addressed return envelope were mailed about a week afterward. This was followed up by a postcard reminder to those who had not mailed back the surveys. A second survey with a cover letter and a self-addressed return envelope were mailed subsequently to the non-respondents. Finally, a thank-you post card was mailed. Fourteen unopened surveys were returned via Return To Sender and one survey signified a deceased notification. One hundred and eight queen breeders returned their completed surveys. This left 105 surveys unreturned or lost in the mail. After receiving and documenting the 108 returned and completed surveys (47% of the original sample population), 73 usable surveys had a *yes* response to the question of whether they bred or sold queens. Thirty-three respondents returned the survey indicating they no longer sold queens or were ineligible for other reasons. Fifty out of the 108 respondents (46 percent) reported using VSH technology. A survey response rate of 47 percent was acquired.



Source: USDA, ARS Data, Queen Bee Breeder Survey, 2013
Figure 3.1: Queen Breeder Respondents by State

3.2. Conceptual Model

Farmers are assumed to make decisions to maximize their present value of expected benefits from production. Let U_0 and U_1 represent the utility of the expected benefits from traditional farming practices and adoption of a new technology respectively. The farmer decides to adopt if $U^*_1 = U_1 - U_0 > 0$. Net benefits, U^*_1, is a latent variable assumed to be a random function of vectors (Walton et al., 2001):

$$U^*_1 = \beta_1\gamma_1 + \varepsilon_1, \qquad (1)$$

where utility (U) is a function set of variables which includes a vector of related parameters (β_1), unknown coefficients such as farm and farmer characteristics (γ_1), and a random error term (ε_1) which is are normally distributed with a mean of zero and variance of one. Since utility is unobservable, representing the queen breeder's decision to adopt (VSH_1) or not adopt (VSH_0) VSH queens is represented by an observable binary variable (Khanna, 2001):

$$VSH_1 = 1 \text{ if } U^*_1 > 0 \qquad (2)$$

$$VSH_0 = 0, \text{ otherwise} \qquad (3)$$

The probit model is a functional association 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 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 risk preference, information sources, farm size, household income, and demographics:

$$Y_i = VSH_i = f(R, I, S, M, D) \quad (4)$$

$$i = (0,1)$$

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.

3.3. Variables Used in the Probit Analysis

Variables used in the probit analysis are listed below. They consist of the dependent variable, information available, risk preference, farm size, farmer characteristics, and income.

Dependent Variable: The dependent binary variable, VSHX, indicates whether or not the breeder adopts VSH queens with the question, "Do you breed or sell queens?" A list of independent variables is described in Table 3.1. Included is risk preference, information available to the bee breeders such as being a member of a local beekeeping club, farm attributes such as number of colonies, income and demographics in this study such as age, education, experience and location of primary residence. A probit model will be used to help determine the impact of these factors on adoption.

Information Available: 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. Many studies have shown that improved information helps facilitate adoption. These include farmer associations (Caviglia and

Kahn, 2001), organizations (Arellanes and Lee, 2003), and information gathered by other farmers (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.

Risk Preference: Risk, RISK, is a key indicator to include in the model because it serves to determine how the risk preference of the potential adopter impacts adoption. Respondents were asked how they perceive risk and how they potentially behave with investment decisions. 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). Risk preference may impact VSH adoption depending on the investment decisions of the potential adopter. In the survey, respondents were asked, “Relative to other investors, how would you characterize yourself?”, (Fausti and Gillespie, 2000). Options consisted of risk taking, risk neutral or risk averse. Depending on the specific characterization of the adopter, risk preference may influence adoption behavior.

Farm Size: One variable represents farm attributes: number of colonies kept in 2011, COLONY. Since the cost of acquiring technology information for a large farm is similar to that of a small farm, there will be a lower cost per unit of area on the larger farm (Perrin et al., 1976). From this, I hypothesize that queen breeders with higher numbers of colonies may be able to disperse cost across their operation and are expected to more likely adopt VSH bees. 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, if the VSH queen producer sold to commercial farms as opposed to smaller, hobbyist farms, I hypothesize they are more likely to adopt VSH technology.

Farmer Characteristics: Four variables represent farmer demographics: experience of breeding and selling queens commercially, EXPER; age, AGE (in years); the level of education of the breeder, EDUC, and the location of residence of the queen breeder, SOUTH. Evidence points to the influence of age in the adoption process (Harrison and Ranier, 1992). Hammet et al. (1992) found age had a negative effect on lumber mill export participation, while Ervin and Ervin (1982) found age had a positive association with soil conservation adoption practices. 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 age of the individual or length of tenure in the workforce has a negative

Table 3.1. 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 Sources	
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 2011
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

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 fact that mostly any person can start breeding queens at 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.

In the present study, it is hypothesized that a positive relationship exists between education level and adoption. Agarwal et al.'s (1999) hypothesis of the relationship between education and technology innovation states: "Level of education is positively associated with ease of use and usefulness beliefs about an information technology innovation." The level of 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.

Income: Utility is a measure of happiness that an individual receives from the consumption of a good or service (Pindyck and Rubinfeld, 2009). A higher income level allows one to consume more of those 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). Kebede et al. (1990) found income had a positive effect on the probability of adoption of single-ox, fertilizer and pesticide technologies in developing countries. It is hypothesized that higher household income will positively influence the probability of VSH technology adoption.

3.4. Estimation

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. VSH case studies show clear progress toward eliminating or at least reducing the use of chemical control (Danka, 2013). 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:

$$p = P[Y = 1] = \Phi\,(x'\beta) + \varepsilon \tag{5}$$

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*. Using the probit model (5) and including the actual variables results in:

$$VSH_1 = \Phi \begin{pmatrix} \beta_1 + \beta_2\mathrm{EXPER} + \beta_3\mathrm{SOUTH} + \beta_4\mathrm{CLUB} \\ +\beta_5\mathrm{AGE} + \beta_6\mathrm{RISK} \\ + \beta_7\mathrm{EDUC} + \beta_8\mathrm{COLONY} + \beta_9\mathrm{INCOME} \end{pmatrix} + \varepsilon \tag{6}$$

where VSH_1 is adoption of VSH, Φ is the cumulative distribution function (*cdf*), β are coefficients to be estimated, *Q* are variables influencing VSH_1 and ε is the error term.

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

This chapter is divided into a few sections. First, the results of the descriptive statistics are given followed by the probit results, the marginal effects and finally, the discussion.

The means and standard deviations of independent variables are presented in Table 4.1. Preliminary analysis of the data reveals that roughly 35% lived in the southern states as their primary residence. Southern states are indicated as MD, DE, DC, WV, VA, NC, SC, WV, KY, GA, AL, MS, FL, LA, AR, OK and TX. California and North Carolina resulted in a high number of queen breeders. This may be due to the high portion of agricultural output which requires pollination from bees (USDA-NASS, 2012a; USDA-NASS, 2012b). Most bee breeders fell between the "baby boomer" age of 48 and 68, with an average age of 56, the youngest being 18 and at the oldest at 81. The number of colonies owned by each respondent varied from as little as six colonies up to 12,000 colonies. Results on educational attainment showed most respondents (84%) had at least some schooling beyond high school. Most breeders (51%) have been in the business between 2-4 years while the remaining breeders' experience is varied up to 55 years. Income distribution was fairly even across all income categories reported, with 43% earning less than $60,000 and 63% earning less than $90,000.

Based on previous research in technology adoption, knowledge or awareness of the technology under consideration should play a role in VSH queen adoption. Our analysis of the data shows the majority of respondents were aware of VSH bees. Over half of respondents were members of at least one beekeeping association. Another potentially critical factor in technology adoption based on previous research is the interaction or contacts with other beekeepers for technical information. Most queen breeders had contact with groups, clubs and vendors.

Another factor potentially influencing technology adoption was preference or attitudes about risk (Kim, 2006). In the questionnaire, breeders were asked a question designed to solicit a choice for risk preference (Fausti and Gillespie, 2000). The results revealed that 37% of respondents claimed to be risk-averse and 63% of respondents characterized themselves as risk-neutral or risk-taking.

Table 4.1 Means and Standard Deviations of Independent Variables Used in the Analysis.

Variable	Mean	S. D.	Minimum	Maximum
EXPER	0.36	0.48	0	1
SOUTH	0.35	0.48	0	1
CLUB	0.57	0.50	0	1
AGE	55.93	12.99	18	81
RISK	0.37	0.49	0	1
EDUC	0.51	0.50	0	1
COLONY	906.61	2207.95	6	12000
INCOME	3.01	1.47	1	5

4.2. Probit Results

The results of the probit model examining VSH adoption behavior are presented in Table 4.2. This includes estimate coefficients for each variable, probability values determining their significance, as well as the standard error which provides an estimate of the reliability of our observed sample mean. Also included is the Log Likelihood function, (-31.834), Percent Concordant (78.7%), Total R-Square, (0.199), Adjusted R-Square (0.078), and number of usable observations, (62).

Years of experience, EXPER, resulted in no significance toward the adoption decision. Location of residence in the southern states, SOUTH, also resulted as a non-significant factor in the adoption of VSH queens.

Information sources of whether or not the breeder was involved in a local beekeeping association, CLUB, yielded no significance. The queen breeder's age, AGE, also resulted in no significance. The risk preference variable, RISK, which controls for aversion of risk turned out to be both positive and significant at the 0.10 level. This result signifies that if the queen breeder is risk averse, the more likely they are to adopt Varroa Sensitive Hygiene queen bees. Education, EDUC, resulted in a positive significance toward the adoption decision. This significance indicates if the queen breeder holds a bachelor's degree or higher, it will be likely that they will adopt VSH queens.

Table 4.2. 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

The farm size variable COLONY did not result in any significance on the adoption decision. Income, INCOME, was another significant variable at the 0.10 level but had a negative influence on adoption decision. This indicates the higher the income of the queen breeder, the less likely they are to adopt VSH queens.

Overall, the queen breeders who are most likely to adopt VSH technology are risk averse in their beekeeping investment decisions and have an education at the bachelor's degree level or higher. Those who are not likely to adopt are those with a higher level of household income.

4.3. Marginal Effects

Marginal effects for each variable are shown in Table 4.4 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.

Table 4.3. 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.

4.4. Discussion

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 and location of residency have been associated with adoption of agricultural technologies, these factors have been shown to not be associated with adoption of VSH queens in the analysis. Descriptive results showed that most respondents had three or less years of queen breeding experience, EXPER, which was not a significant influence in VSH adoption. This suggests not much time and effort may be necessary to learning the skill of queen breeding. Location of primary residence, SOUTH, resulted in zero 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 VSH technology originated in Baton Rouge, Louisiana, results showed 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 other sources. Even though our regional variable, SOUTH, and our farming experience variable, EXPER, were not influential factors in adoption, they were included in the model to allow comparison of the results to others in previous similar studies.

The variable that represents information available to the queen breeder, CLUB, did not exhibit a significant association with VSH adoption in the analysis. This may be because the information provided through local clubs or beekeeping organizations may not have been a very successful way of passing 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. This can easily be seen in our descriptive results that the sample of queen breeders ranged from 18 to 81 years of age.

The variable, RISK, controls for the aversion to risk preference, has shown to be both significant and positive. This implies that if the queen breeder is risk averse, the more likely they are to adopt VSH technology. Sometimes risk 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 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 significance in the analysis and therefore appears to influence the adoption decision. A higher education is an influential factor in utilizing VSH technology in their queen breeding business. Most (84%) of the respondents have at least some college education or higher which coincides with the results in the current study. This may be because with a higher education results in more information exposed to the queen breeder and hence, a higher probability of the queen breeder being aware of VSH technology.

Farm size, COLONY, has shown to have no significance in influencing the adoption decision of VSH queens in our analysis. 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 system, 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. These results suggest that the higher category of household income of the queen breeder, the less likely they are to adopt VSH queens. This might be due to a similar reason earlier 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 that since higher household income could potentially mean higher profits, they could be more likely be better prepared for unforeseen circumstances.

CHAPTER 5. SUMMARY AND 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 such as the VSH line of bees to help restore and maintain colony health. VSH has been considered to be an environmentally friendly and sustainable alternative to harmful chemicals that can help re-establish our pollinating bee population.

Previous literature suggests certain factors have impacts on the adoption decision process. Such factors include demographics, attitudes toward risk, socioeconomic and other factors that are related to the farm. This study examined the adoption of VSH queens in the beekeeping and queen breeding industry in the United States. The main objective in this study is to investigate the factors involved in the adoption decision process of VSH queens in the beekeeping and breeding industry.

Based on Dillman's Total Design Method, mail surveys were sent to 228 queen breeders across the United States. With two contacts made to the list of queen breeders, a response rate of 47 was attained. Overall, queen breeding experience fell between 2-4 years with experience spanning as high as 55 years. Roughly 35% reported their primary state of residence was located in the southern region of the US. About 57% of respondents reported being a member of a local beekeeping club or organization. Most of the survey respondents fell between the ages of 48 and 68. About 37% have characterized themselves as risk averse in their beekeeping investment decisions. 84% of queen breeders held some additional education beyond high school. Respondents reported owning from as little as six colonies up to 12,000 colonies with a mean of 900 colonies. Finally, income distribution was fairly even across all income categories reported with 37% of respondents reported having an annual household income of $90,000 or greater.

5.1. Summary of Results

A probit analysis was used to analyze the data. Three variables were found to be significant and had an influence on the adoption decision. The analysis suggests 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. Holding a bachelor's degree or higher has an important role in influencing VSH adoption behavior. 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.

5.2. Conclusions

This is one of the first studies to provide an analysis of VSH queen adoption in the United States. Further, it seeks to analyze the factors involved in the VSH adoption process. Risk aversion, level of education, and household income were found to influence VSH adoption decisions.

Current programs exist in the beekeeping industry to help encourage the adoption of VSH bees and similar Varroa-resistant lines of bees on both a large and small scale basis. Risk aversion and education level are positive influential factors in influencing the probability of VSH adoption in our study. Those who have an aversion to risk have shown to be more likely to adopt VSH queens which may imply a need to protect their beekeeping related business from the destructive capabilities of the Varroa mite. Beekeeping clubs and organizations could invite speakers in to their meetings to help diffuse the information and benefits of VSH technology. Those that hold a bachelor's degree or higher may imply that queen breeders who are hold a higher education may be more willing to adopt a new technology such as VSH. Extension services could target students in higher educational institutions with their programs and field days for information on VSH technology. The results also suggest that the level of household income of the queen breeder may be an important determinant of VSH adoption. Targeting those in the beekeeping industry with a lower income with educational programs and demonstrations may help increase VSH adoption in the beekeeping community.

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 colony collapse and economic damages associated with Varroa mites. Such an appeal to risk-averse, better educated queen breeders and beekeepers may be more effective, given the improved understanding of the factors influencing adoption of VSH queens that resulted from this research. Since overall attitudes and beliefs play an important role in VSH adoption, it emphasizes the need to concentrate efforts at targeting potential VSH adopters to maximize VSH and Varroa-resistant bee adoption. This focus is necessary to increase overall awareness of VSH technology, to underline the importance of its link in the beekeeping industry, and therefore, how it is interconnected with our ecosystem and our environment.

5.3. Limitations

Although the results have shown to be mostly in line with previous literature, improvements that may have a potential impact include a greater number of observations and sample size. This could have included a wider range of queen breeders in the U.S. The list of queen breeders was provided by the USDA, ARS Honey Bee Breeding, Genetic and Physiology Laboratory which was derived from a list of purchasers of breeder queens. This also could be improved by expanding the scope of purchasers to include more than one list of breeders that adopted other lines of Varroa-resistant queens. 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. In reflection, even though limitations are recognized in this study, they contribute to the structure of my research in helping improve the existing studies and literature.

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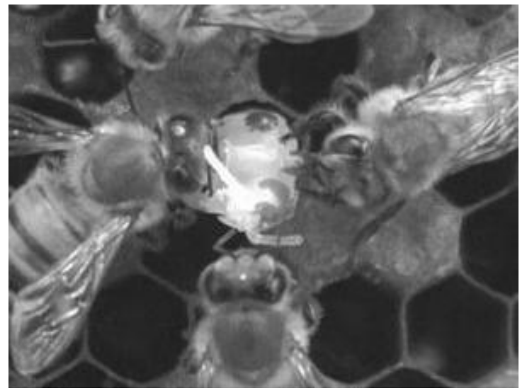
Varroa Sensitive Hygiene (VSH) Queen Supplier Questionnaire

1. **Do you breed or sell queens?** (Mark ☒ one)
   - ◻ No ***(Please return questionnaire in envelope. Thanks!)***
   - ◻ Yes

2. **How many years have you bred or sold queens commercially? _________ years**

3. **In what state is your primary residence?**

   ____

4. **Are you currently a member of a beekeeping association?** (Mark ☒ all that apply)
   - ◻ No
   - ◻ American Beekeeping Federation
   - ◻ American Honey Producers Association
   - ◻ A local club or other (*please specify*)

     ____

5. **What is your age? ________ years**

6. **What is your gender?** (Mark ☒ one)
   - ◻ Female
   - ◻ Male

7. **To how many beekeeping publications (such as magazines) do you currently subscribe? For example, an annual subscription would be considered <u>one</u> publication.**

   _______ No. of publications

8. **Have you heard of any of the following lines of queens?** (Mark ☒ all that apply)
   - ◻ Varroa Sensitive Hygiene (VSH)
   - ◻ Russian Varroa-resistant
   - ◻ Suppression of Mite Reproduction
   - ◻ None of the above

9. **Have you ever sought information about any of the following lines of queens?** (Mark ☒ all that apply)
   - ◻ Varroa Sensitive Hygiene (VSH)
   - ◻ Russian Varroa-resistant
   - ◻ Suppression of Mite Reproduction (SMR)
   - ◻ None of the above→ ***(Skip to 11)***

10. **What year did you first seek out information about the following lines of queens?**

    VSH _____________year

    Russian _____________year

    SMR _____________year

11. With how many queen breeders do you discuss technical queen breeding issues __on a regular basis__?

________ No. of queen breeders

12. How many times, in 2011, did you have beekeeping educational or business contact with each of the following? Please include meetings, seminars or workshops, and personal contacts like phone calls.

No. times in 2011

_______Beekeeping groups or clubs
_______Beekeeping vendors
_______USDA
_______Cooperative Extension Service
_______State Department of Agriculture

13. Do you use the internet to get technical information on beekeeping? (Mark ☒ one)

□ No
□ Yes

14. Relative to other investors, how would you characterize yourself? (Mark ☒ one)

□ I tend to take on substantial levels of risk in my investment decisions.
□ I neither seek nor avoid risk in my investment decisions.
□ I tend to avoid risk when possible in my investment decisions.

15. What is the highest level of education you have completed? (Mark ☒ one)

□ Less than high school
□ High school diploma or GED
□ Some college or technical school
□ Bachelor's degree
□ Advanced/graduate degree

16. Do any of your family members plan to take over your queen breeding operation when you retire? (Mark ☒ one)

□ No
□ Yes
□ I don't know

17. Do you have a job __other than selling queens__? (Mark ☒ one)

□ No → ***(Skip to 19)***
□ No, but I am retired from a job other than queen breeding → ***(Skip to 19)***
□ Yes

18. How many hours per week do you work for the other job(s)? _________ hr/week

19. At any time this year 2012, which of the following line(s) of queens did you sell? (Mark ☒ all that apply)

□ Varroa Sensitive Hygiene (VSH)
□ Carniolan
□ Italian
□ Hygienic Behavior Bees
□ Russian-Varroa Resistant
□ Suppression of Mites Reproduction (SMR)
□ Hybrid (___________) x (____________)
□ ________________________

20. Did you sell __breeder queens__ in the past five years? Please consider __only__ breeder queens; not queens included with package bees, nucs or complete hives.

□ No → **(Skip to 21)**
□ Yes

If yes, please list annual sales (quantity and average price, excluding shipping). For 2012, please include sales to date.

a. For **VSH breeder queens**:

	Queens sold	price
2008	_____________	$______ each queen
2009	_____________	$______ each queen
2010	_____________	$______ each queen
2011	_____________	$______ each queen
2012	_____________	$______ each queen

b. For **all breeder queens, except VSH**:

	Queens sold	price
2008	_____________	$______ each queen
2009	_____________	$______ each queen
2010	_____________	$______ each queen
2011	_____________	$______ each queen
2012	_____________	$______ each queen

21. If you sold VSH breeder queens, were they? (Mark ☒ all that apply)

- ◻ Artificially inseminated with VSH trait
- ◻ Mated with VSH drones
- ◻ Mated with drones (not VSH trait)

22. Did you sell individual queens in the past five years? Please consider only individual queens; not breeder queens or queens included with package bees, nucs, etc.

- ◻ No → **(Skip to 23)**
- ◻ Yes

If yes, please list annual sales (quantity and average price, excluding shipping). For 2012, please include sales to date.

a. For **VSH queens**:

	Queens sold	price
2008	____________	$______ each queen
2009	____________	$______ each queen
2010	____________	$______ each queen
2011	____________	$______ each queen
2012	____________	$______ each queen

b. For **all queens, except VSH**:

	Queens sold	price
2008	____________	$______ each queen
2009	____________	$______ each queen
2010	____________	$______ each queen
2011	____________	$______ each queen
2012	____________	$______ each queen

23. This year (2012), did you sell queens (other than breeder queens) included with package bees, nucs or complete hives?

- ◻ No → **(Skip to 24)**
- ◻ Yes

If yes, please list sales (quantity and average price, excluding shipping) estimated for 2012.

a. For **VSH queens only**:

	Quantity sold	price
Package bees	___________	$______each
Nucs	___________	$______each
Complete hives	___________	$______each

b. For **all queens, except VSH**:

	Quantity sold	price
Package bees	___________	$______each
Nucs	___________	$______each
Complete hives	___________	$______each

24. If you sold VSH queens, individuals or as part of packages, nucs, complete hives or cells, were they? (Mark ☒ all that apply)

- ◻ Artificially inseminated with VSH trait
- ◻ Mated with VSH drones
- ◻ Mated with drones (not VSH trait)

25. What percentage of your VSH queens were sold to beekeeping customers who were:

_______ % commercial (>300 colonies)
_______ % small scale (25-300 colonies)
_______ % hobbyists (<25 colonies)
100% Total

26. For next year (2013), please tell us how the quantity of breeder queens, individual queens, package bees, nucs and complete hives (both VSH and other) you plan to sell will change compared to 2012. Write the number by which you plan to change your sales inventory, indicating "-" for decrease and "+" for increase. Put "0" if no change.

	Number	**-/+**
a. VSH breeder queens	_______	_______
b. Other breeder queens	_______	_______
c. VSH individual queens	_______	_______
d. Other individual queens	_______	_______
e. VSH package bees	_______	_______
f. Other package bees	_______	_______
g. VSH nucs	_______	_______
h. Other nucs	_______	_______
i. VSH complete hives	_______	_______
j. Other complete hives	_______	_______

27. What percentage of your queens do you ship nation-wide, state-wide and locally?

Nation-wide	_______ %
State-wide	_______ %
Locally	_______ %
Total	**100%**

28. Do you resell queens that you have previously bought from another queen breeder?

□ No □ Yes

29. Have you received VSH germplasm (queens or semen) within the last five years?

□ No □ Yes

30. If yes, please indicate your source(s):

____

____

31. If yes, which types of breeder queens: (Mark ☒ all that apply)

- □ VSH Yellow
- □ VSH Dark
- □ Carniolan
- □ Cordovan
- □ Hygienic Italian

32. The queens you make were grafted from: (Mark ☒ all that apply)

- □ VSH breeders
- □ 1st generation outcross queens
- □ other breeding that included VSH

33. If "other breeding that included VSH", please describe. (Examples include queens of survivor colonies mated to VSH two generations ago).

____

____

____

34. Please suggest what you think should be done with the VSH breeding program – specific issues that should be addressed?

____

____

____

35. Please suggest any practices or ideas you have for dealing with Varroa mites?

____

____

____

36. How many bee colonies did you keep in 2011, for honey production, pollination services and your breeding program?

________ colonies in 2011

37. If you sell (sold) out all of your queens this year, do you plan on producing more queens for sale this year?

□ No □ Yes

38. What were gross revenues (total sales before costs) from all beekeeping related business, *including queen sales*, in 2011:

$______________ in 2011

39. What were gross revenues (total sales before costs) from queen sales *ONLY* in 2011:

$______________ in 2011

Queen sales *ONLY* were _______% of gross revenues from all beekeeping sales in 2011.

40. What was your household income from all sources in 2011? (Mark ☒ one)

- □ Less than $30,000
- □ $30,000 to $59,999
- □ $60,000 to $89,999
- □ $90,000 to $119,999
- □ $120,000 or more

41. What percentage of your household income in 2011 came from your beekeeping related business (including queen sales)?

________ percent

Thank you very much for taking time to complete this questionnaire. Please insert it in the self-addressed, postage-paid envelope provided and mail it today to:

Dr. John V. Westra
Department of Agricultural Economics
101 Martin D. Woodin Hall
Louisiana State University
Baton Rouge LA 70803

VITA

Julie Leiby was born and raised in the farm lands of eastern Pennsylvania where she graduated from Moravian College and earned her Bachelor of Arts in 2005. Although her love for the arts still remain, she decided to pursue her other interests which led her to the Department of Agricultural Economics at Louisiana State University in 2011 to earn her Master of Science with a focus in natural resources and sustainability.