FACTORS INFLUENCING ADOPTION OF INTEGRATED PEST MANAGEMENT PRACTICES IN NORTHEAST GREENHOUSE ORNAMENTALS

A Thesis

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ABSTRACT

We conducted ninety-four surveys among small growers of greenhouse ornamental in three Northeastern states to examine factors that influence IPM adoption. We construct four alternative dependent variables describing the extent of IPM adoption, and employ Standard Logit, Ordered Logit and Tobit models to indentify factors affecting IPM adoption. We find that IPM adopters are more likely to operate large farms, use more full time workers, and have diversified operations to include vegetables. Greenhouses that suffered serious disease problems are less likely to adopt IPM practices; the position of head growers in the greenhouse operations is also influential in IPM adoption. Our findings reveal that unavailability of biological control agents is a great hindrance for growers to adopt IPM. Our analysis also highlights substantial difference between the self-reported IPM measure and the three objective IPM measures.

BIOGRAPHICAL SKETCH

Jie Li was born in 1987 in Quzhou, China. She spent most of her childhood in a rural place of China. At the age of 12, she went to Handan City for her junior and senior high school.

Afterwards, she was matriculated by Beijing University of Post and Telecommunication. Majoring in Economics, she received her Bachelor of Science degree in June 2009. Because of her love for agriculture and rural development, during her college years, she assisted in conducting market research and has contributed to a number of international research efforts on organic food as well as work with the Hebei Qimei Agriculture and Technology Co. Ltd. in Hebei, China.

With a keen interest in agriculture and economics, she decided to pursue higher education in agricultural economics abroad. She began her graduate study at the Dyson School of Applied Economics and Management at Cornell University in August 2009.

This is dedicated to my parents, especially to my beloved father

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LIST OF ABBREVIATIONS

USDA	United State Department of Agriculture
ERS	Economic Research Service
IPM	Integrated Pest Management
NE	New England
NH	New Hampshire
VT	Vermont
MH	Maine

CHAPTER 1
INTRODUCTION

1.1 Introduction

In the United States, about 25,000 farming operations produce nursery and greenhouse crops with a total annual wholesale value of about $14 billion (NASS/USDA 2009). Greenhouse ornamentals represent a key component of this production, providing a lucrative means of crop diversification and income to supplement traditional vegetable and fruit farms (NASS/USDA 2009). The income-generating potential of greenhouse ornamentals far exceeds that of most traditional crops in New England (NE) and the greater northeast region. Based on the most recent NASS/USDA survey that focus on 6 of the 13 Northeastern states, the annual wholesale value in 2004-05 exceeded $460 million, an increase of 17.5 percent since 2002. About 10 percent of the operations produce 65 percent of the revenue for this crop nationally, with the majority of producers managing comparatively small operations, which are endemic of the Northeastern agricultural economy. This industry is thus critical to the health, expansion and sustainability of the northeast's rural economy.

Ornamentals are grown for their aesthetic value to the consumer, with zero to minimal tolerance for pest and pathogen damage. For this reason, chemical pesticides are used repeatedly to control many persistent pests and diseases, yet greenhouse growers' heavy reliance on chemical pesticides may not be sustainable. In fact, recent studies report increased resistance to pesticide in various herbivores and diseases, and chemical approaches to control could eventually become ineffective (Mariyono 2008). Although Northeastern growers have expressed anecdotal interest in the use of biological control within an integrated pest management (IPM) program, little is known about the extent of IPM adoption in the region as well as the factors that facilitate or limit adoption. Thus it becomes very interesting and important to examine what factors affect adoption of IPM practices by greenhouse ornamental growers in Northeastern states.

We hypothesize that a variety of factors (e.g., size of greenhouse, grower's confidence, grower's knowledge, production problems) influence adoption of IPM practices among greenhouse growers in three Northeastern states—Maine, Vermont and New Hampshire. To this end, we surveyed ninety-four growers of greenhouse ornamentals in those states. After inputting the data, we develop alternative measures of IPM adoption and employ discrete choice econometric models to assess factors influencing the likelihood of adopting IPM practices.

We find that growers in the Northeast believe that IPM practices work more efficiently to control insect problems than disease problems, and they prefer not using IPM practices if they are experiencing a serious disease problem. The unavailability of biological control agents and other IPM supplies is a great hindrance for growers that are adopting IPM practices. We also find that the head grower position is a key one in an ornamental greenhouse, since this person could decide to adopt IPM practices, and analysis suggests that those people tend to adopt IPM practices for their greenhouse. As we expected, revenue from growing vegetables is another driving factor to facilitate IPM adoption, and the more full-time workers a greenhouse employs, the greater the likelihood that it adopts IPM practices.

In addition, several IPM studies focus on the role of labels for food products while little is known about labeling issues on non-food sectors such as organic cotton, IPM labeled ornamentals and eco-friendly furniture. We argue that consumers' willingness to pay premiums for such labeled food products as organic food, local food, eco-friendly food and GMO-free food are due to their concern for both their own health and for reasons related to the environment sustainability. At the same time, growers tend to adopt new technologies whenever food sectors are involved. The thesis confirms this point, indicating that northeastern growers are more likely to adopt IPM technology when the growers diversify crops to include vegetables. In terms of non-food products, the concern for environmental sustainability is the primary reason for consumers to purchase organic cotton or IPM ornamentals. This thesis also indicates that in addition to reducing the input cost, greenhouse ornamental growers who tend to adopt IPM technology care about the environmental sustainability.

1.2 The Integrated Pest Management (IPM) Concepts

Integrated Pest Management

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest control, in order to reduce the reliance on a purely chemical approach and instead use a combination of common-sense practices. A typical IPM program uses current and comprehensive information on the life cycles of pests and their interaction with the environment, combined with standard pest control methods, to manage pest damage with the least danger to people, property and the environment. IPM methods could protect the environment, the people working in agriculture, and consumers due to the reduction in the use of pesticides. The U.S Department of Agriculture (USDA), for its part, defines IPM as

> *"Integrated Pest Management (IPM) is the implementation of diverse methods of pest controls, paired with monitoring to reduce unnecessary pesticide applications. In IPM, pesticides are used in combination with other crop management approaches to minimize the*

effects of pests while supporting a profitable system that has negligible negative effects."

An IPM program can be applied to both food (e.g., fruit) and non-food crops (e.g., ornamental greenhouse crops and garden lawns). Conceptually, IPM falls between the conventional and organic production system. Conventional growers rely heavily on chemical pesticide at certain times of the year without considering pest populations; however, heavy use of pesticides could potentially by harmful for consumers, agricultural workers and the environment. Conversely, though organic growers use no synthetic pesticides and fertilizer, because of intensive labor requirement and inherent fluctuating production yields, organic products often require a high price premium which only certain consumers can afford. Rather than relying on heavily on chemical pesticides and eliminating synthetic pesticides, IPM production techniques minimize their use to lower and safer levels. Thus, IPM could be more cost-efficient and brings more stable production yields than organic production methods. Moreover, it is safer for the consumer and agricultural workers and more sustainable for the environment when compared with conventional controls.

IPM is not a single pest control method but, rather a series of pest management evaluations, decisions and controls. When practicing IPM, farmer or growers need to be aware of the potential for pest infestation follow four steps including 1) Set Action Thresholds; 2) Monitor and Indentify Pests; 3) Prevention; and 4) Controls (Figure 1).

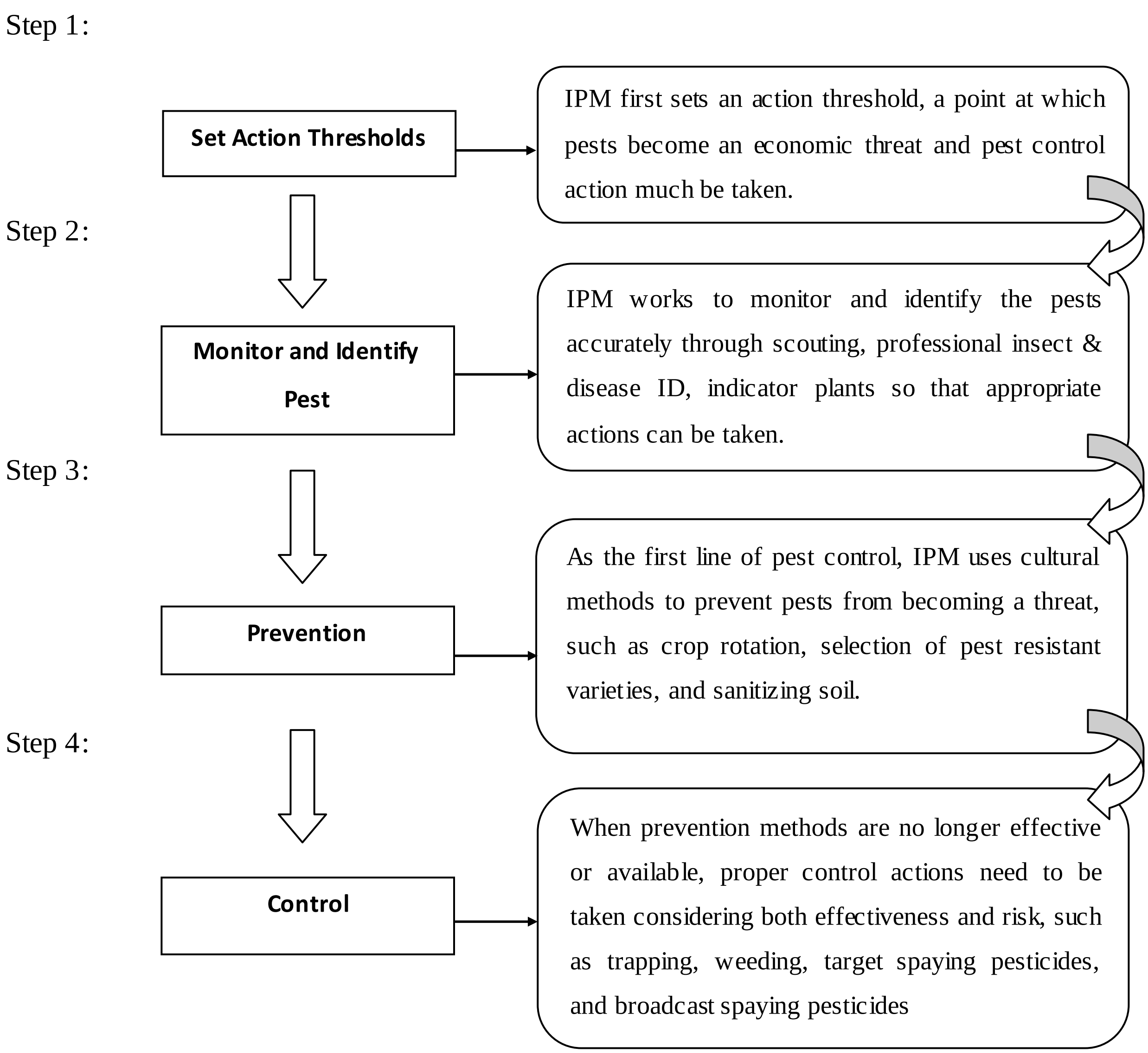

Figure 1 Four Steps of How IPM Programs Work

1.3 Greenhouse Ornamental Industry

The United States leads the world in the production and marketing of flowers, cut foliage, potted plants, bedding plants, and other nursery crops. This industry has experienced strong growth during the 1990's and into the 21st century. According to USDA, grower cash receipts gained about $400 million annually through to the year 2000. This growth followed a decade of 10 percent annual increases in the 1980's. Greenhouse and nursery crops were the fourth largest crop group based on farm cash receipts in 2003 with cash receipts for greenhouse and nursery crops estimated at $14.3 billion. U.S. per household purchases of ornamental crops was $140 in 2003 (UDSA 2004). The overall value of sales from the greenhouse, nursery and floriculture comprise 5.6 percent of the total value of agricultural products sold in the United States in 2007 (USDA 2007). Therefore, this industry has the potential benefits for economic development in Northeastern states.

In 1997, U.S. consumers spent $16 billion on floriculture ($54 per capita), which was the 12th highest in the world in terms of per capita expenditures on indoor flowers/plants. In addition, $9 out of $54 was used to purchase cut flowers and the rest for flowering and foliage plants (USDA, 2004). The leading countries with respect to per capita consumption of floriculture products are Japan, Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Norway, Sweden, and Switzerland (Johnson 1997). Americans, on the other hand, are by far the leading consumers of outdoor landscaping plants. In 1997, U.S. consumers spent $37 billion on environmental horticultural products, or $138 per capita. U.S. consumers express great interest in purchasing ornamentals products for various reasons, such as an expression of love or friendship or, as a way to express thankfulness and blessings, and these ornamental crops are grown for their own value to the consumers. “Beautiful and perfect” are the most important elements that impact a consumer’s purchasing decisions, thus, ornamental greenhouse growers use pesticides repeatedly in order to minimize visual damage that threatens growers’ profit, but at the cost of environment in the long run. IPM practices have been introduced in the greenhouse ornamental industry to solve these problems, though with limited knowledge of IPM methods and about consumer attitude toward IPM labeled ornamentals.

CHAPTER 2

LITERATURE REVIEW

IPM practices have received considerable attention in the agricultural economics literature. Many diverse aspects about IPM programs have been studied, including the impacts of IPM programs on the environment and on farmers, consumers' attitudes toward IPM products; government support and investment in IPM programs; extension programs for spreading IPM adoption; factors influencing IPM adoption, and approaches to measure IPM adoption. This literature review addresses these issues, paying particular attention to the determinants of IPM adoption and approaches to measure IPM adoption.

Impacts of IPM on the Environment and Farmers

Extensive research has been conducted on the adoption of IPM techniques in the agricultural economics literature because of their potential to deliver positive environmental impacts. Some studies argue that IPM approaches are environmentally-friendly, and could largely reduce the total use of chemical pesticides and highly toxic class of pesticides on IPM-trained cotton farms (Khan et al. 2007). Such decreases in use of chemical pesticides was also found in the production of soybeans, pecan, celery, cabbage, grapes and other crops when farmers adopted IPM practices (Trumble et al. 1997; Harris et al. 1998; Burkness et al. 2008; Bentley 2009; Song and Swinton 2009).

Most studies find positive impacts from IPM practices on adopters' profit and reduced cost due to input rationalization. These studies often use cost benefit analysis to show that IPM techniques at least maintained and even reduced total input costs with no countervailing loss in production (Fernandez-Cornejo 1996; Harries et al. 1998; Williams et al. 2005; Dasgupta et al 2007; Burkness and Hutchison 2008). Other researchers focus on the environmental implications of adopting IPM practices. Mullen et al. (1997), for example, estimate that the peanut IPM program generated annual environmental benefits totaling $844,000. A recent study by Mullen et al. (2005) demonstrates high returns on public investments in IPM in California on a wide variety of agricultural products.

Consumers' Attitudes toward IPM Products

Another stream of research focuses on consumers' interest in purchasing IPM products. Research has shown that consumers would like to pay a price premium for IPM labeled products especially those consumers with higher annual income. Younger individuals who always purchase organics, or frequently visit farmers markets are potential consumers for IPM products (Govindasamy and Italia 1998, 2001). Florax et al. (2005) conduct a meta-analysis of the willingness to pay for reduction in pesticides use, and find significant premium estimates. The chosen payment method and the safety image delivered by eco-labeling, integrated pest management, and organic, are important drivers for such price premiums.

Government and Public Support for Spreading IPM Programs

The above studies address environmental benefits of IPM, and also demonstrate high value of IPM programs in terms of society's willingness to pay for reductions in pesticide use. These findings make a case for public support to IPM programs and highlight the importance of accounting for environmental impacts in agricultural policy design. Most recent studies indicate that continued government interest and increased investments in promoting IPM in response to serious environmental problems and health issues associated with chemical-intensive agriculture. For instance, IPM program supported by the Indonesian government reduced the use of pesticides, and increased production yields (Resosudarmo 2001, 2008). The Philippine government launched a nationwide IPM program to promote more sustainable approaches to pest control (Templeton et al. 2010). Some political efforts are being made in the European Union to promote the adoption of IPM practices in order to reduce the use of pesticides (Meissle et al. 2010). The U.S. government also provides financial incentives for growers that implement IPM practices. Specifically, the Environmental Quantity Incentives Program (EQIP) provides incentives for IPM adoption (Castle and Naranjo 2009).

IPM Extension Programs and IPM Specialists

Though farmers express positive attitudes to IPM production methods (Moser et al. 2008), a number of studies indicate that continuing educational efforts and training on IPM practices are very important for IPM adoption among farmers (White and Wetzstein 1995; Lameck et al. 1998; Mariyono 2008; Castle and Naranjo 2009). A study conducted in Nepal shows that farmers are willing to pay for IPM training; it also finds that farmers need support from local villagers (Atreya 2007). Extension programs such as farmer field school, field days, and extension agent visits have been often used to encourage IPM adoption. Various studies report that the most popular is farmers field school, even though it is the most expensive; and field days are the most cost-effective means to enhance adoption of simple IPM practices (Mauceri et al. 2007; Prudent et al. 2007; Ricker-Gilbert et al. 2008). Extension agents visiting could offer more complex and up to date disease-control methods for farmers who expect to use advanced IPM practices (Rosenberger 2003; Ricker-Gilbert et al. 2008).

Factors Influencing IPM Adoption

A few studies examine how farmers' characteristics influence the decision to adopt IPM production methods. These studies reveal that younger, more-educated and less-experienced farmers tend to have a friendlier attitude toward IPM methods (Papadaki-Klavdianou et al 2000). Chaves (2001) finds a strong link between farmer's educational attainment, wealth, choice of recommendations and IPM adoption rates and Govindasamy (1998) demonstrates that risk-averse farmers are less likely to adopt IPM practices. Other researchers study additional factors that influence IPM adoption among farmers. For example, Mahmoud and Shively (2004) argue that access to IPM technology and IPM availability increase growers' adoption of IPM. Moreover, several studies show that such factors as farm size, gross sales, growers' work status, market destination, adopters' perceptions of IPM relative to their needs and availability of labor are important determinants of IPM adoption (Fernandez-Cornejo et al. 1992; Ashraf 1995; Alston and Reding 1998; Lameck 1998; Fournier 2005; Blake et al. 2007).

Approaches to Measure IPM Adoption

The agricultural economics literature has employed several approaches to measure IPM adoption ranging from simple measures to more elaborated approaches to measurement. Measuring adoption of IPM is not straightforward. Nowak et al. (1996) posit that there may be multiple, not mutually exclusive levels to measuring IPM adoption. Earlier studies employ self-reported measures of IPM adoption (Baker and Smith, 1987; Fernandez-Cornejo et al., 1992). More recently, studies employ binary variables to distinguish IPM growers from conventional growers. For example, Fernandez-Cornejo et al. (1992) classify IPM adoption as "a binary variable equal to 1 if one or more IPM techniques are adopted, 0 otherwise." Dasgupta et al. (2007) characterize IPM farmers as those practicing at least one method among biological control, light traps, smoke, organic production, crop rotation, manual clearing, and enemy plants.

Other studies employ more elaborate measures of IPM adoption in which farmers are classified into several categories. For example, Ridgley and Brush (1992) use the combination of more than one measure to produce a scale where those who score highest are considered to be the strongest or "ideal" adopters. The authors define four components (pest monitoring,

monitoring of beneficial, weather monitoring and economic thresholds) based on a standardized scale of 1-5, with 5—representing the highest level of adoption. Rickert-Gilbert et al. (2008), for their part, identify several IPM adoption levels for rice in Bangladesh and classify IPM farmers into ‘simple’ (e.g., using disease resistant varieties), ‘intermediate’ (e.g., using trap systems) and ‘complex’ (e.g., using beneficial insects). Thomas et al. (1990) use a dichotomous (0, 1) adoption measure for each of three practices: scouting, using pheromone traps to determine insects trends, and selectively using insecticides, then a scale of adoption ranging from zero to three is produced by adding these variables.

USDA’s Economic Research Service (ERS) released a set of guidelines in 1994 with the goal of establishing a baseline estimate of IPM adoption and for monitoring progress toward policy adoption goals (Vandeman et al. 1994). These guidelines recognize that there is no universal definition of IPM practices. The report explains that IPM systems are highly variable, depend greatly on the crop and range from chemical to biological based, along a continuum. The USDA approach divides farmers into four categories, including "No IPM", and three levels of adoption (Low, Medium and High), according to the number of practices considered under the umbrella of IMP methods. For example, in the USDA approach, a "low" level IPM farmer scouts and applies pesticides according to thresholds for one kind of insects or mites; a “medium” level IPM farmer conducts “low” level activities plus one or two additional IPM practices indicative of IPM practices; and a "high" level IPM farmer practices additional IPM practices than their medium-level counterparts.

Summary of Literature Review and Contribution

In sum, the literature suggests that IPM techniques generally increase profitability for farmers, reduces dependence on agrichemicals, requires important public investments in extension and grower education, is valued by consumers, and yields environmental benefits. In spite of strong public support to increase IPM adoption among ornamental industries in Northeastern States, and farmers' interest in the use of IPM practices, little is known about the extent of IPM adoption in the region as well as the factors that facilitate or limit IPM adoption. Moreover, the agricultural economics literature has not addressed issues pertaining IPM adoption among non-food, high value greenhouse ornamental crops. Thus, in order to fill this gap, I develop an empirical model and a set of hypotheses to study the factors that influence IPM adoption among ornamental crop growers in Northeastern states. In addition, previous studies only employed binary and categories variables to measure IPM adoption. This study employs binary and categories variables, and provides an alternative variable by using continuous IPM scores to measure IPM adoption. Therefore, we develop different ways to measure IPM adoption and use the appropriate econometrics models (Logit, Tobit and Ordered Multinomial Logit) to identify factors affecting IPM adoption.

CHAPTER 3

SURVEY INSTUMENT AND EMPIRICAL MODEL

3.1 The Survey Instrument

A survey instrument was developed and conducted by Margaret Skinner from University of Vermont to measure the level of IPM adoption and to assess the factors that facilitate (or hinder) adoption of such practices among ornamental growers in the Northeastern states of Vermont, New Hampshire and Maine. In the survey, ornamental growers are asked to describe the characteristics of their ornamental operations; rate the importance of various insects, disease problems in their greenhouse crops; identify the management practices they use for commercial production (including IPM practices); state the kind of production system best describes the ornamental operation between conventional and IPM; assess the performance of IPM methods relative to conventional practices; list the challenges that limit greater IPM adoption and use of biological control agents; and describe the needs for assistance on the adoption of IPM practices from researchers and extension specialists. Selected portions of the survey instrument are shown in Appendix I.

Earlier experiences in soliciting information from growers indicate that they are weary of receiving surveys in the mail without an immediate expectation of a direct benefit, and thus the return rate is often low. Therefore, the data collection strategy consisted of a survey conducted among attendants to three IPM workshops held in January 2009 in the states of Maine, New Hampshire and Vermont. Each workshop had between 40 and 50 participating growers. The incentives to ensure attendance and survey responses were pesticide credits (which they need to retain an applicator license), and door prizes donated from corporate workshop sponsors. We employed additional ways to conduct the survey, including email lists of ornamental growers in the three states, distribution of the survey during the Annual State Farm Shows and the New England Greenhouse Conference, and one-on-one grower interviews conducted by extension specialists in the tri-state region.

In total, the survey consists of 14 questions, covering such topics as demographics, operation characteristics, production problems, management practices, primarily IPM or primarily conventional of a greenhouse operation, opinion of IPM performance, and challenges or limiting factors.

3.2 Empirical Model

In our empirical approach we employ four alternative measures of IPM adoption (self-reported, binary-objective, censored continuous IPM scores, and three-tiered measures) to identify factors that explain the level of IPM adoption. These factors include the degree of insects and disease challenges faced by ornamental growers in the Northeast; the level of confidence on IPM practices in comparison to conventional practices; the level of IPM knowledge of growers; the availability of IPM biological control agents; the revenue assortment for Greenhouse Ornamentals; the size of ornamental greenhouse; the position of the respondents in the operation, and the location of greenhouse operations. In a general equation form of the model yields:

(1) ADOPTION= F [Insect Problems, Disease Problems, Grower Confidence, Grower Knowledge, Availability of Biological Control Agents, Revenue Assortment, Size of the Operation, Position of the Respondents, Location of the Operation]

3.3 Dependent Variables: Measure of IPM Adoption

Measuring the adoption of IPM is not straightforward. Based on information provided in the survey, we constructed four dependent variables to measure IPM adoption for Greenhouse Ornamentals. One is based on a self-reported subjective measure, while the other three are associated with objective measures as explained below.

3.3.1 Subjective Dependent Variable

This measure is a self reported measure of IPM adoption. In the survey instrument we asked respondents whether IPM or "conventional control" best described the operation. We denote *Y_selfreport* as the subjective dependent variable, which is a dichotomous variable equal to one if a respondent states that he/she is an IPM grower, zero otherwise.

3.3.2 Objective Dependent Variables

Objective measures are based on a set of questions asking respondents in which management practices they use in their commercial operations. With the help from a scientist expert on IPM of Greenhouse Ornamental, and from U.S. Environmental Protect Agency, 36 IPM management practices from survey questions are classified into four categories:

1) Monitoring, related to monitoring for pests, includes the following six activities: "use of sticky cards", "use of indicator plants", "regular scouting", "hiring a commercial scout", "using degree days to track pests", and "foliar testing".

2) Pest Identification, related to accurately pest identification, includes the following four activities: “identification pests/diseases yourself”, “professional insect/disease ID”, “use of disease test kits”, and “sending plants out for disease testing”.

3) Prevention, related to managing the crop to prevent pests from becoming a threat, includes the following 17 activities: “screen vents”, “crop rotation”, “inspect new plant shipment”, “disinfect growing areas”, “sanitize pots or use new ones”, “sanitize soil or use new soil”, “reemay plant covering”, “culture indexed plants”, “fallow crop space”, “use DIF”, “drip irrigation”, “remove weeds”, “recycle water”, “soil testing”, “water testing”, “pest resistant varieties”, and “cover floor with weed cloth”.

4) Control, related to evaluating the proper control method so that appropriate method could be taken, includes the following nine activities: “rotate pesticide classes”, “release predators, parasites”, “spray insecticides on floor/benches”, “use pesticides less toxic to beneficial”, “use microbial biocontrol”, “spot pesticide treatment”, “use chemical pesticides”, and “preventative pesticide treatment”. (Appendix II)

The first objective dependent variable, denoted as *Y_binary*，is a binary variable which equals one for IPM growers, zero otherwise. In order to be classified as an IPM grower, a respondent has to report using at least one activity from the “monitoring” list, one from the “pest identification” list, four from the “prevention” list and three from the “control” list. The other two objective measures of dependent variables are created on the basis of above information.

The second objective dependent variable, denoted as *Y_IPMScore*, is continuous variable using IPM scores to represent grower’s degree of IPM adoption. Non-IPM growers have a score of zero, as defined by the binary variables above. For IPM growers, each respondent has an IPM score based on how many activities they use for “prevention” and “control”. The expert points out that in Greenhouse Ornamentals, “prevention” activities are as twice as important as “control” activities. Therefore, the weight for “prevention” activities is 2/3, and the weight for “control” activities is 1/3. The IPM score is calculated as 2/3 times the number of “prevention” activities plus 1/3 times the number of “control” activities. Thus, the higher the number of “prevention” and “control” activities, the higher the IPM scores. We could use the following equation to calculate the IPM scores. In mathematical notation:

(2) $\text{IPM Score} =$
$(\text{number of activities used for "}control\text{"})$

Thus, if a grower is a Non-IPM grower, defined by the first measure, his/her IPM score is 0. If a grower is an IPM grower, for example, and he/she emplys eight activities from the “prevention” list and six from the “control” list, then his IPM score is 2/3*8+1/3*6=7.33

The third objective measure of IPM adoption divides ornamental growers into three levels (Non-IPM grower, Low-IPM grower, High-IPM grower). This objective dependent variable denoted as *Y_IPMlevel* includes three levels: “0” which is the lowest level for Non-IPM growers; “1” which is a moderate level for Low-IPM growers; and “2” which is a high level for High-IPM growers. Non-IPM growers are identified in the same way as in the binary objective measure. For IPM growers, according to their IPM scores calculated in the second objective measure, an IPM grower with a score below 9.3 is a Low-IPM grower, all else are High-IPM growers. The reason why we use 9.3 as a cutoff score between Low-IPM and High-IPM growers is because the expert opinions indicate that only if a grower has used at least two-thirds of the “prevention” and “control” actions, then we could conclude that the grower masters IPM techniques in the Greenhouse Ornamentals. In addition, whether to use 9.3 or 8.3 does not greatly impact the results.

Thus, a Non-IPM grower has a level “0”. An IPM grower, for example, with an IPM score of 6.3 (from the second objective measure) is classified as a Low-IPM grower; and with an IPM score of 10.3 is classified as a High-IPM grower.

3.4 Explanatory Variables

The survey instrument has several questions pertaining to factors that may influence IPM adoption, as well as many potentially relevant controls. However, only few of these questions can be converted directly into variables. Most variables needed to be constructed from the information collected in the survey. We constructed three categories of independent variables including type of production problems, limitations or challenges for IPM adoption, and operation characteristics. We briefly describe how they were constructed from the survey instrument below.

Type of Problems

In the survey, we ask 38 questions about disease and insect problems, covering most production problems growers face in their greenhouses. Respondents use three levels to rate the relevance of each problem from 1 to 3. A “1” means that the specific problem is of low importance, a “2” means that the specific problem is of moderate importance, and “3” means the specific problem is of high importance. Based on these responses, we created two variables to represent the relative importance of disease and insect problems. Thus, *DiseaseAvg* equals the average of the 19 questions related to diseases; and *InsectAvg* equals the average of the 19 questions on insects and mites. We expect that the relative importance of pests versus diseases may be relevant for adoption of IPM. IPM performance in controlling disease and pest problems are important factors influencing the decisions to adopt IPM. Thus we include the following as explanatory variables in order to examine their effects on IPM adoption:

DiseasesAvg – Average of 19 different disease problems reported.

InsectAvg – Average of 19 different insect problems reported.

Types of Challenges and Limitations Hindering IPM Adoption

A set of dummy variables are created in order to study challenges and limitations for growers adopting IPM practices, and three types of hindrances are extracted from 42 challenges and limitations from the survey. Each one measures a certain limitation that growers face. The survey uses three levels 1, 2 and 3 to measure the extent of each limitation: 1 means "a little hindering", 2 means "moderately hindering" and 3 means "greatly hindering". Because our objective is to study the factors that greatly influence IPM adoption decision, which factors challenge the growers matters, but what extent the challenges are does not. Therefore, we generatedthree new dummy variables listed below:

Unavailability- this variable examines the degree of availability of IPM supplies. It includes such questions as availability of biocontrol agents and general IPM supplies among others. This variable equals one if the aggregate average of the relevant questions is greater than 1, which means unavailability is a hindrance for IPM adoption, zero otherwise.

Unreliability- this variable refers to possible lack of confidence in IPM practice to control pests. It includes such issues as hard-to-control insects, hard to control diseases, hard to control weeds. This variable equals one if the average of the scores to the above questions is greater than one, zero otherwise. A 1 means that a grower believes that unreliability is a great hindrance for them to adopt IPM.

Knowledge Limit- this variable indicates grower's lack of knowledge about IPM. It includes such questions as knowledge about pest biology, how to use biological controls. This variable equals one if the average score for these relevant questions is greater than one, zero otherwise. A "1" therefore means that a grower believes that lack of knowledge is a great hindrance for IPM adoption.

Operation Characteristics

IPM adoption may be influenced by several operation characteristics such as the source of the revenue, the size of the operation, the position of the respondents, the location of the greenhouse. Each of these is discussed in greater detail next.

Crop mix- many operations have a mix of crop types. A greenhouse ornamental operation mostly grows cut flowers; they may also grow vegetables and indoor, non-flowering plants such as bedding plants, and foliage plants. Several studies show that consumers are willing to pay a price premium for IPM labeled vegetables. We believe that the percentage of revenues from vegetable production could be an important predictor of IPM adoption; hence, a continuous variable *PercentVeg* is generated to measure the percentage revenue coming from vegetable.

Size of operation- IPM practices are more labor intensive than their conventional counterpart, because they require workers with the ability to identify pests, to scout and to monitor regularly. It is difficult to use area under cultivation to measure the size of an operation because the production units have acres under protection and in the open at the same time. Production under protection is much more intensive than in the open, and they are not comparable. Therefore, the best alternative to measure size is to use the number of full time workers, denoted as *Fullworker*. Five levels are used in this survey; "1" means having less than 1 full time worker, "2" means having between 1 and 2 full workers, "3" means having between 3 and 4 full time workers, "4" means having between 5 and 6 full time workers, and "5" means having over 6 full time workers.

Position of the respondents- the survey reports information about the role that respondents play in their organization. There are three categories including owners, workers and head grower. In this paper, we generate *owner* which is a binary variable, it equals 1 if a respondent is the owner of the operation, and zero otherwise. We also generate *headgrower* which is a binary variable as well. Since both owners and head growers may be the persons that is most familiar with the operation; they could decide, to some extent, which production system to use.

Location- we construct a vector of dummy variables for the three states where the survey was conducted (Maine, Vermont, and New Hampshire). In this paper, *NH* is a dummy variable which equals one if the greenhouse is located in New Hampshire, and zero otherwise. Another variable is also constructed, denoted as *ME*, which equals one if the greenhouse is located in New Hampshire, zero otherwise.

In summary, in this paper, four models will be discussed corresponding to four alternative dependent variables measuring IPM adoption. Nine factors which cover most of survey questions are studied in these models. The results contribute to identify factors that influence IPM adoption and may also reveal effective strategies to spread IPM adoption among small greenhouse ornamentals.

3.5 Data Description

We obtained 94 useable responses that allow us to assess the factors that influence IPM adoption in these three states. The descriptive statistics of the four dependent variables and the nine explanatory variables are presented in Table 1. The variable *Y_selfreport* has a mean of 0.58, as 54 of the 94 respondents reported that they have adopted IPM practices, the others considered themselves as conventional growers. The variable *Y_binary* has a mean of 0.62 which is a little larger than the mean of *Y_selfreport*. According to this measure, 58 out of 94 respondents are "IPM grower", while others are identified as "Non-IPM grower". The variable *Y_IPMlevel* has three categories, and the highest level is assigned a value 2. The mean of *Y_IPMlevel* is only 0.713 which suggests that most ornamental growers fall into the non-IPM and Low-IPM levels. For the continuous variable *Y_IPMScore*, the mean score for this sample is 4.411, and the maximum sample score is 11.3. However, theoretically, based on the survey questions and those management practices, the full score for *Y_IPMScore* (using all of prevention and control actions) is 14.3 (Table 1).

Table 1. Descriptive Table of IPM Model Data

Variable	Description	Mean	Std Dev	Min	Max
Dep. Variable					
Y_selfreport	self report as IPM grower (yes=1, no=0)	0.575	0.497	0	1
Y_binary	objective measure of IPM grower (yes=1, no=0)	0.617	0.489	0	1
Y_IPMScore	IPM score each grower could get	4.411	3.834	0	11.3
Y_IPMlevel	three IPM levels each grower could rank	0.713	0.633	0	2
Indep. Variable					
Headgrower	position of respondent (yes=1, no=0)	0.340	0.476	0	1
PercentVeg	percentage of total revenue from growing vegetables	15.691	25.331	0	100
Fullworker	number of employed full time worker	2.588	1.482	1	5
NH	location of business in New Hampshire (yes=1, no=0)	0.192	0.396	0	1
InsectAvg	seriousness of insect problem in greenhouse crops	0.850	0.512	0.1	2.3
DiseaseAvg	seriousness of disease problem in greenhouse crops	0.758	0.564	0	2.1
Unavailability	= 1 if to order biological control agents is a great, hindrance, =0 otherwise	0.128	0.336	0	1
Unreliability	= 1 if lacking of confidence in the reliability of IPMs is a great hindrance to implement them, =0 otherwise	0.468	0.502	0	1
Knowlimit	= 1 if knowledge limit of IPM measure is a great hindrance to implement them, =0 otherwise	0.149	0.358	0	1

Production problems have greatly influence on IPM adoption. The average insect problem is 0.85 which is greater than 0.75—the average disease problem, and the minimum number for the average insect problem is 0.05, which suggests that all the greenhouses face insect problems albeit at different degrees. However, the summary statistics in Table 1 shows that not all the greenhouses experienced disease problems. Among three dummy variables for IPM adoptions, "unreliability" (growers lacking of confidence in IPM practices) has a larger sample mean in comparison to "unavailability" and "knowledge limit", this suggests that most ornamental growers do not have confidence about the effectiveness of IPM practices.

Several operations in our sample only grow vegetables in their greenhouses; however, the sample mean of percentage revenue from vegetables is 15.7 percent, which is not large since these are primarily ornamental operations. The sample mean of *Fullworker* is 2.59, which suggests that, on average, greenhouse operations hired 3 to 4 full time workers. We have a hypothesis that the more full-time labor an operation has; the more likely it is to adopt IPM practices. The survey instrument characterizes the respondents into three following categories: owners, workers, and head growers. In the sample, 34 percent of respondents are head growers, 29 percent of respondents are owners. Regarding the location of the operations, 18 respondents are from New Hampshire, and 54 respondents are from Maine.

CHAPTER 4

REGRESSION RESULTS

Table 2 exhibits regression results for the models in with *Y_binary, Y_IPMScore*, and *Y_selfreport* as dependent variables. The table presents the estimated coefficients and their marginal effects. We employ a standard logit model for the first regression and the third regression (variables *Y_binary* and *Y_selfreport*) because the dependent variables are binary. We employ a tobit model to estimate the second regression, because the dependent variable, *Y_binary*, is continuous and censored at zero.

4.1 Regression 1: IPM Binary Measure—Logistic Model

Table 2 presents results of the logit model for IPM adoption measured as a binary variable. Overall, this model seems to fit the data reasonably well, the absolute value of log pseudo likelihood is 31.9 which is low; the Wald test indicates that the overall model is significant given the degrees of freedom, the probability of rejecting holds at the 1.9 percent level of significance, rejecting the null hypothesis in favor of significance of the model specification. Pseudo R^2 is 31.3 percent suggesting that the model explains about a third of the variability of the dependent variable.

Column 1 in Table 2 presents the estimated coefficients of the variables *Y_binary*. Regarding production problems, *DiseaseAvg* shows a positive and significant effect on IPM adoption, implying that if a grower experiences a large degree of disease problems, he/she is less likely to adopt IPM practices. The estimated marginal effect suggests that with a one unit increase in average disease problems, the probability of adopting IPM drops by 54.3 percent. Although not significant, the positive effect of *InsectAvg* on IPM adoption makes sense, given that IPM practices such as scouting, pest identification, and biological control agents are relative good ways to control insects rather than to cope with diseases. Therefore a large degree of insect problems will increase likelihood of adopting IPM method.

Table2. Estimated Regression Results and Their Marginal Effects [a]

Variable name	Binary IPM Measure Logit model		IPM Scores Tobit model		IPM Self-report Logit model	
	Coefficient (std err)	Marginal Effect	Coefficient (std err)	Marginal Effect	Coefficient (std err)	Marginal Effect
Constant	-2.693*** (1.506)		-3.181* (1.952)		1.271* (0.857)	
Headgrower	1.469** (0.566)	*0.214*	2.614*** (1.009)	*2.614*	-0.290 (0.539)	*-0.044*
PercentVeg	0.024*** (0.014)	0.005	0.035*** (0.016)	0.034	0.0004 (0.012)	0.0005
Fullworker	1.068*** (0.473)	0.227	1.831*** (0.411)	1.801	0.024 (0.195)	0.003
InsectAvg	2.704 (1.955)	0.575	5.750** (3.021)	5.654	-1.258 (1.527)	-0.173
DiseaseAvg	-2.551* (1.635)	-0.543	-5.613** (2.730)	-5.520	-1.786 (1.502)	0.246
Unavailability	-2.351** (1.246)	*-0.516*	-3.446** (2.007)	*-3.446*	0.850 (1.397)	*0.087*
Unreliability	-0.795 (0.58)	*-0.188*	-0.894 (1.071)	*-0.894*	-1.187*** (0.595)	*-0.228*
Knowlimit	1.128 (1.301)	*0.181*	2.297 (2.135)	*2.297*	-3.316** (2.054)	*-0.628*
NH	1.113 (0.821)	*0.180*	1.678* (1.139)	*1.678*	-1.849*** (0.715)	*-0.391*
# Observations	72		72		72	
Log Pseudolikelihood	-31.944		-152.088		-37.648	
Wald Chi^2/F	19.84		5.47		14.01	
Prob > Chi^2/F	0.019		0.000		0.122	
Pseudo R^2	0.313		0.100		0.235	

*, **, *** denote coefficient estimates statistically significant at the 0.15, 0.10, and 0.05 level, respectively. Standard errors are presented in parentheses. Each variable is defined in Table 1.
[a], the number of observation in those models is 72 instead of 94 is because there are some missing values when constructing the independent variables

Next, we look at the types of limitations and hindrances to IPM adoption. The coefficient of *unavailability* (unable to access biological control agents and other IPM supplies) has a negative and significant effect on IPM adoption, indicating that lack of access to biological control agents and other IPM supplies results in a 51.6 percent decrease of probability of adopting IPM in greenhouses (Table 2). Although the coefficient of *unreliability* is not significant in this model, the negative direction is as expected. The coefficient of *knowlimit* is statistically insignificant.

The coefficient of *PercentVeg*, the percentage revenue from growing vegetables, is positive and significant. In other words, the larger the revenue generated from growing vegetables, the larger the likelihood of IPM adoption. If growers believe that consumers are willing to pay for a price premiums for IPM labeled vegetables, growers may want to adopt IPM practices in their greenhouses. Our results indicate that a one percent point increase in *PercentVeg* increases the probability of adopting IPM by 0.5 percent.

Our results indicate that size of operation *Fullworker* has a significant effect on IPM adoption. The positive effect of increasing one level of full time workers raises the probability of adopting IPM practices by 22.7 percent. Here, as the IPM expert pointed out, IPM practices tend to be more labor-intensive than conventional controls since they require more labor to do scouting, monitoring and sanitation. Hence, greenhouses with more labor are more likely to adopt IPM practices.

The coefficient of *Headgrower* is positive and significant. The positive effect suggests that the probability of being classified as an IPM operation increases if the respondent is the head grower. This makes sense, because the head grower in a greenhouse operation is familiar with the production practices and could decide whether or not to use IPM practices. We observe that when the respondent is a head grower, the probability of a greenhouse operation to be classified as IPM increases by 21.6. We dropped the variable *Owner* it because it was not statistically different from the intercept.

Though the state dummy variable is not significant in this model, it has a positive relationship with the dependent variable. However this dummy variable becomes negative and significant in the model with the self-reported measure as dependent variable. This may imply that farmers in New Hampshire use many IPM practices, but are perhaps unaware of what exactly IPM is. In terms of *ME,* we dropped it from the first model as it was not statistically different from the intercept.

4.2 Regression 2: IPM Scores Measure—Tobit Model

In this model, we use *Y_IPMScore* as the dependent variable, an objective IPM adoption measure. It consists of continuous IPM scores and is censored at zero. Thus, we employ a tobit model to estimate this regression. Table 2 presents the goodness of fit of this model as well. The F-test shows that the overall model is significant at the one percent level of significance. The pseudo R2 is 10 percent which is modest, suggesting that the model explains about one tenth of the variability of the dependent variable.

Column 3 in Table 2 shows that the variable *DiseaseAvg* has a significant negative effect on IPM adoption, implying that if a grower experiences a large degree of disease problems, he/she is less likely to adopt IPM practices. The estimated marginal effect of *DiseaseAvg* indicates that a one point increase in disease problems results in a 5.52 decrease in their IPM adoption score. The significant and positive coefficient of *InsectAvg* on IPM adoption suggests if a grower faces serious insect problems, then he/she is more likely to adopt IPM. The estimated marginal effect of *InsectAvg* suggests that with a one unit increase in average insect problem, the

IPM score increases 5.65. In another words, the dependent variable IPM scores are higher if the greenhouse operation experiences a more serious insect problems, and less serious disease problems.

Regarding the variables that capture limiting factors, the results indicate that *unavailability* demonstrates a robust, significant and negative effect on IPM adoption. Here if lack of availability to biological control agents and other IPM supplies is a great hindrance for a grower to adopt IPM, then his/her IPM score drops by 3.45 points. Thus, the grower may choose not to use biological agents but rather to use chemical pesticides to control pests. In this model, the coefficient of *unreliability* is not significant, but the negative sign is consistent with expectations. The coefficient of *knowlimit* lacks statistical significance.

The coefficient of percentage revenue from growing vegetables is positive and statistically significant. The marginal effect indicates that with a one percent increase in *PercentVeg*, the IPM score increases 0.034. The size indicator for each operation is captured by the variable *Fullworker* and it has a significant positive effect on IPM adoption. The marginal effect of *Fullworker* reveals that increasing full time workers by one level raises the IPM score by 1.80. The coefficient of *Headgower* is significant and positive, indicating if a respondent is a head grower, the IPM score of his/her greenhouse operation increases 2.61, when holding other variables constant. The coefficient of *NH* is significant in this model and it has a positive effect on IPM scores, the coefficient of *NH* indicates that growers from New Hampshire have an average IPM score which is 1.68 point higher than those growers from the other two states. In terms of ME, we dropped it since it was not statistically different from the intercept.

4.3 Regression 3: IPM self-report Measure—Logistic Model

Because the dependent variable *Y_selfreport* is binary, we employ the logistic method for estimation. Overall, the fit of this model is inferior to the fit of models in which the dependent variable is an objective measure of IPM adoption. The overall model is not significant since we now fail to reject the test of significance of the model at a 10 percent level (Prob>Chi^2=0.122). The pseudo R^2 suggests that this model explains about one fourth of the variability of the dependent variable.

Column 5 in Table 2 presents the coefficients of *DiseaseAvg* and *InsectAvg*. Though not significant in this model, the direction of *DiseaseAvg* is as expected. In this model, the coefficient of *InsectAvg* is not statistically significant, and its sign changes to negative which is contrary to what we expected to find.

Regarding the challenges and limitation varibles, the coefficient of *unavailability* is not statistically significant in this model, though the direction of this explanatory variable is as expected. The table 2 exhibits that the coefficient of *unreliability* is significant and has a negative effect on IPM adoption, implying that if growers have a lack confidence in IPM practices, the probability of adopting IPM practices in their greenhouses decreases by 22.8 percent. In other words, greenhouse growers may not be confident in the effectiveness of IPM practices in comparison to conventional methods. The coefficient of *knowlimit* in this regression has significant and negative effects on IPM adoption, suggesting that if growers lack knowledge about IPM practices, then the probability for him/her to adopt IPM practices decreases by 62.8 percent.

The estimated coefficient for *PercentVeg* is not significant in this model, though its sign is as expected. In addition, the estimated coefficient of *Fullworker* is not statistically significant in this model specification, but the direction is as expected. In terms of the position of operation *Headgrower*, it is not significant in this model, and its direction is in contrary our expectation. The state dummy variable "NH" has significant and negative effects on IPM adoption in this model; the marginal effect of this variable indicates that if a greenhouse locates in New Hampshire, the probability for this greenhouse to adopt IPM practices decreases by 39.1 percent.

4.4 Regression 4: Objective IPM levels Measure—Ordered logistic model

The dependent variable in the ordered logistic model, *Y_IPMlevel*, takes three levels: Non-IPM grower, Low-IPM grower and High-IPM grower. Thus, we employ an ordered multinomial logit method for estimation. We present the model estimates in Table 3. Overall, the model fits the data well. The Wald test indicates the null hypothesis that all coefficients are equal to zero can be rejected at the 1.5 percent level of significance. The pseudo R2 is 29.8 percent, suggesting that the model explains about one third of the variability of the dependent variable. Table 3 presents the estimated coefficients, log odds ratios, as well as their corresponding marginal effects.

Table 3. Ordered Logistic Regression Results and its Marginal Probability Effects

Variable name	Three IPM Levels				
	Coefficient (std err)	Log odds Ratios	Non-IPM grower IPM Value=0 (Marginal Effects)	Low-IPM grower IPM Value=1 (Marginal Effects)	High-IPM grower IPM Value=2 (Marginal Effects)
Constant	-3.181* (1.952)				
Headgrower	1.119*** (0.513)	3.061***	-0.196** (-0.102)	-0.160** (-0.087)	0.037 (0.027)
PercentVeg	0.012 (0.009)	1.012	-0.002 (-0.002)	-0.002 (0.002)	0.0003 (0.000)
Fullworker	1.109*** (0.396)	3.030***	-0.211* (-0.053)	0.181* (0.057)	0.030** (0.017)
InsectAvg	3.906* (2.390)	49.716*	-0.745** (-0.385)	0.639** (0.351)	0.107 (0.077)
DiseaseAvg	-3.530** (1.911)	0.029**	0.673* (-0.300)	-0.577* (0.276)	-0.096 (0.067)
Unavailability	-2.697** (1.149)	0.067**	0.587* (-0.186)	-0.555* (0.187)	-0.032 (0.022)
Unreliability	-0.393 (0.543)	0.675	0.075 (-0.108)	-0.0649 (0.094)	-0.011*** (0.015)
Knowlimit	1.634 (1.463)	5.125	-0.221** (-0.116)	0.136* (0.059)	0.085 (0.135)
NH	0.707 (0.548)	2.209	-0.12 (-0.090)	0.095 (0.069)	0.024 (0.026)
# Observations	72				
Log Pseudolikelihood	-45.814				
Wald Chi^2/F	20.55				
Prob > Chi^2	0.015				
Pseudo R^2	0.289				

Three levels of IPM growers include: (1) Non-IPM grower (value=0), (2) Low-IPM grower (value=1), (3) High-IPM grower (value=2).
*, **, *** denote coefficient estimates statistically significant at the 0.15, 0.10, and 0.05 level, respectively. Standard errors are presented in parentheses. Each variable is defined in Table 1.
Marginal probability effects are estimated at sample means.

The coefficients of *InsectAvg* and *DiseaseAvg* are significant in this model and have the expected signs. The coefficient of *InsectAvg* has a positive effect on IPM adoption, and its log odds ratio is 49.72. For instance, this indicates that with a one unit increase in average insect problems, the odds of being in a higher IPM level is 49.72 times greater versus being in a lower IPM level. The magnitude of the effect of a one unit increase in *InsectAvg* on IPM Level is large, given that the maximum insect score in our sample is only 2.3. In this model, *DiseaseAvg* has a significant negative influence on IPM adoption levels. Its odds ratio is 0.03 (Table 3) which indicates that a one unit increase in average disease score decreases the odds of being in a higher level of IPM category by 97.1 percent. These results make sense, since insect-related problems may be more relevant for IPM adoption than disease-related problems.

The coefficient of *unavailability* is positive and statistically significant. The odds ratio indicates that if a grower believes that accessing IPM supplies and biological control agents is difficult, the odds for this grower being in the higher IPM level decreases by 93.3 percent. In other words, unavailability of IPM supplies or biological control agents greatly limits growers IPM adoption. The coefficient of *unreliability* is insignificant, but exhibits a negative effect on IPM adoption as expected. The coefficient of *knowlimit* is not significance, and its sign is contrary to expectations.

Even though percentage revenue from vegetables shows a positive effect, it is not significant. The coefficient of *Fullworker* exhibits a significant and positive effect on the level of IPM adoption. This suggests that larger greenhouse operations are more likely to adopt IPM practices. In particular, for greenhouses in New England, having one to two additional full-time workers has a strong effect on IPM adoption, the log odds ratio indicates that with a one level increase in full time worker, the odds of being in a higher IPM level category increases by 203 percent. The estimated coefficient of *Headgrower* is positive and statistically significant; its log odds ratio indicates that if a respondent is a head grower, then he/she is 3.061 (Table 4) times more likely to move to a higher level of IPM in comparison with a non-head grower. The coefficient of *NH* is not statistically significant, suggesting that there may not be differences in IPM adoption levels across the three states.

Marginal Effects

In the ordered logistic regression, coefficients measure the changes in odds of moving into higher adoption categories, assuming that changes are constant across categories. Marginal effects measure the probability that a grower moves to a higher IPM-level category in response to a change in an explanatory variable, holding everything else constant.

The marginal effects shown in Table 3 further contribute to analyze factors affecting IPM adoption. For example, a one level increase in full-time workers decreases its probability of being in the Non-IPM level by 21.1 percent, while the probability of being in the Low-IPM level increases by 18.1 percent and the probability of being in the High-IPM level increases by three percent. In addition, the results suggest that a one point increase in the disease problem score increases the probability of being in the Non-IPM level by 67.3 percent. At the same time this decreases the probability of being in the Low-IPM and High-IPM level by 57.7 percent and 9.6 percent respectively.

As discussed above, the effects of changes for average insect problems are opposite to those associated with changes in disease problems. A one point increase in insect problem scores may decreases the probability of being in the Non-IPM level by 74.5 percent, and it may increases the probability of being in the Low-IPM level by 63.9 percent, and it may increase High-IPM level by 10.7 percent. These marginal effects are consistent with our discussion about odds ratios, but provided more details regarding the impact of explanatory variables on IPM adoption.

4.5 Summary of the results

In summary, our results suggest that disease problems and insect problems matter to IPM adoption. When a greenhouse grower faces serious disease problems, then he/she is less likely to adopt IPM. Instead, and if a grower faces serious insect problems, then he/she is more likely to adopt IPM. In terms of limiting factors, our results indicate that lack of availability of biological control agents and other IPM supplies restricts IPM adoption among Northeastern greenhouse growers. In addition, our results suggest that greenhouse growers who diversify crops to include vegetables are more likely to adopt IPM than growers focusing solely on ornamentals. In addition, larger greenhouse operations (measured as the number of full-time workers) exhibit higher levels of IPM adoption.

Our results suggest that the models with objective measures as dependent variables (*Y_binary, Y_IPMScore, and Y_IPMlevel*) provide similar results regarding factors influencing IPM adoption. However, we found substantial differences between these three models using objective measures and the model that uses self-reported measure (*Y_selfreported*). The coefficient of *Fullworker, DiseaseAvg* and *unavailability* all show significant effects on IPM adoption in the former models, in contrast, they become statistically insignificant when using self-reported measure as the dependent variable. In sharp contrast, the coefficients of *unreliability* and *knowlimit*, which are not statistically significant in the models with the objective measures, but become statistically significant when using the self-reported IPM adoption dependent variable.

CHAPTER 5

CONCLUSION AND FUTURE RESEARCH

5.1 Conclusion

This study provides the first known estimation of factors that may limit or facilitate IPM adoptions among small growers of ornamental plants in the Northeast region. Given the recent attention to the IPM production method favored among both farmers and the public with an interest in “sustainability”, and the fact that the adoption rate of IPM practices among greenhouse ornamental producers in Northeastern states is quite low, the findings of this study may contribute to identify ways to promote IPM adoption among greenhouse ornamentals.

Our analysis suggests that farmers in those areas are not clear about what IPM production systems are, and what practices constitute an IPM system. Thus, extension specialists and educators can use the classification proposed in this study to enhance farmers’ knowledge on IPM practices. Our results indicate that head growers in the greenhouse operation are the people whom IPM promoters should talk to and persuade; since head growers tend to adopt more IPM practices compared with others. Another implication is that greenhouses with more full time workers and greenhouses that specialize in growing vegetables are more likely to adopt IPM practices than the rest; therefore, these types of operations should be a priority for extension efforts. IPM extension specialists and educators should also consider that greenhouses which face serious disease problems are less likely to use the IPM methods, so those greenhouses are less likely to be potential IPM adopters.

We also find that unavailability of biological control agents is a great hindrance for farmers to adopt IPM; which means that IPM suppliers must help solve this problem. They could widely broadcast their products so as to make sure the farmers know where they could get the biological control agents and what kinds they need for specific pests. At the same time, lack of confidence in IPM controls for pests and disease could also limit growers' adoption of IPM practices. Therefore, IPM suppliers may need to advance their technologies and enhance the reliability of IPM controls. Cooperation with the extension programs and educators in research is another thing that IPM suppliers could do. First, extension specialists should easily interact with many farmers, regarding what IPM practices should be used, extension specialists could also provide such information as where the farmers could get IPM supplies. Second, close cooperation with universities could enhance the reliability of IPM practices, for example, different IPM practices are appropriate for different stages in the growth cycle. Extension specialists and educators could make sure farmers use the right IPM supplies and biological control agents at the right time in the right way.

Our results in Table 2 show an interesting phenomenon. We find that big differences exist between objective measures and self-reported measures, which indicates that farmers and policy makers evaluate IPM standards differently. Self-reported IPM measure may lack objectivity and are likely to be biased and conflate IPM adopters; this may be due to financial incentive programs used by state governments (Castle and Naranjo 2009) to promote IPM adoptions and IPM labeled products that have a price premium. Both of them could generate extra benefits for IPM growers. This requires that government and policy makers have a strict surveillance on products labeled as IPM, including monitoring their production process, following strict standards, using a formal certification agency, and establishing a complete traceability system. At the same time, it may raise concerns about whether existing financial incentives for IPM adoption are efficient. Other programs to promote IPM adoption such as providing IPM supplies could also be considered by policy makers.

5.2 Future Research

While this study provides valuable insights on factors influencing IPM adoption, it certainly has some limitations that need further research. Though this study provided one objective method to measure IPM adoption, this measure may be suitable for ornamental greenhouse but may not apply to other crops since different measures for IPM. Selection bias may also exist in this study, given that all the surveys were mailed to the farmers or operations that attended the IPM workshops in January 2009. The fact that they attended the IPM workshop suggests that they are interested in, or already adopted IPM practices, so the survey samples we collected may not represent all the greenhouses in the Northeast. Another limitation of this study is that we collected samples in three states. We analyze them together as a whole, but different states may have their own problems, so the result may have area bias and may not be applicable in all three states.

Future research should conduct cost-benefit analyses and should also develop production functions of IPM and conventional greenhouse ornamentals to conduct rigorous comparative studies. It also desirable to eliminate the selection bias by mailing the IPM survey randomly to all the greenhouses in Northeastern states, not just to the greenhouses that interested in adopting the IPM method. In addition, further research efforts should analyze the data in three states separately so that extension programs and IPM educators could have a clear picture of what they should focus on in each state. If common factors exists in all three states, then the researchers or extension specialists may focus on that primary limitation and the results could apply to promote IPM practices in other Northeastern states. Otherwise different actions may need to be taken in each state in order to meet different growers' needs. For example, states may have different needs in terms of broadcasting general knowledge of IPM, training the growers, and creating connection between growers and biocontrol suppliers.

APPENDIX

APPEDIX I: SURVEY INSTRUMENT

Survey of Needs for Pest Management in Greenhouse Ornamentals in Northern New England

We are conducting this survey to determine pest management priorities for growers in ME, NH and VT. Research and outreach programs will be developed to meet grower needs based on the results. YOUR ANSWERS WILL BE TOTALLY CONFIDENTIAL.

1) What type of horticultural business or organization are you affiliated with and what is your position? (Check all that apply)

Retail greenhouse:_____ Wholesale grower:____ Interiorscapes:__________
Cut flower grower:_____ Landscaper:________ Extension System:_______
Garden center: _______ State agency:_______ Federal agency:_________
IPM consultant: ______ Co/Owner:_________ Head grower:__________
Greenhouse worker:____ Univ. researcher:_____ Research tech.: _________
Pesticide supplier/distributor: _____ Biocontrol supplier/distributor: ____
Other (specify):____

2) Where is your business or office located? (Check 1)

☐ Maine ☐ New Hampshire ☐ Vermont ☐ Other______________

(where?)

3) What percentage of your revenue comes from these crops (% of total revenue)? Total should equal 100%.

Bedding plants	Flowering potted	Foliage plants	Perennials	Cuttings/ Plugs	Cut flowers	Vegetables
Other:		Other:		Other:		

4) How many square feet of greenhouse do you use?

1 – 10,000 ________ 10,001 – 25,000 ________ 25,001 – 50,000 __________

50,001 – 75,000 __________ 75,001 – 100,000 ________ over 100,000__________

5) How many acres do you use to grow perennials and other plants outside?

None _________ Under ¼ ___________ ¼ -½ ___________ 1–2 _____________ 2-4 ___________ 4-6 _________ over 6______________________(how many?)

6) How many hired workers (equivalent to full time) do you employ?

None _____ 1-2 _______ 3 - 4 ______ 5–6 ______ over 6 _________(how many?) Not applicable ___________

7) Rate the importance of these pest, disease and production problems in your greenhouse crops <u>over the past 3 years</u>.

I am not directly involved with growing greenhouse ornamentals and therefore won't answer this section. □

Pest or Crop Management Problem	Low	Moderate	High
Diseases			
Anthracnoses			
Bacterial leaf spots or cankers			
Botrytis blight			
Canker diseases			
Crown gall			
Damping off			
Downy mildews			
Fungal leaf spots			
Fusarium wilt			
Phytophthora root, stem or crown rots			
Powdery mildew			
Pythium root, stem or crown rots			
Rhizoctonia root, stem rot or blight			
Rust diseases			
TSWV/INSV(thrips-vectored viruses)			
Verticillium wilt			
Black root rot – *Thielaviopsis*			
Other (specify):			
Other (specify):			
Insects & Mites			
Aphids			
Black vine weevil			
Cyclamen mites			
Broad mites			
Fungus gnats			
Lace bugs			
Leaf feeding beetles			

Leaf feeding caterpillars			
Leafhoppers			
Leafminers			
Mealybugs			
Scales			
Shore flies			
Spider mites and other mites			
Thrips			
White grubs			
Whiteflies			
Other (specify):			
Other (specify):			

Crop Production			
Algae and/or moss			
Environmentalcontrol(heating/cooling)			
Fertility and fertilization (pH, EC, etc.)			
Irrigation and/or watering			
Potting media (quality, drainage, etc.)			
Rodents			
Slugs & Snails			
Waste water treatment/disposal			
Weather (frost, heat, drought, etc.)			
Weeds			
Other (specify):			

8) What management practices do you use for commercial production? (Check <u>all</u> you use)

____Sticky cards
____Indicator plants
____Screen vents
____Crop rotation
____Regular scouting
____Hire commercial scout
____Professional insect/disease ID
____Inspect new plant shipments
____Rotate pesticide classes
____Identify pests/diseases yourself
____Use deg. days to track pests
____Foliar testing
____Disinfect growing areas
____Sanitize pots or use new ones
____Sanitize soil or use new soil

____Reemay plant covering
____Culture indexed plants
____Spot pesticide treatment
____Fallow crop space
____Use DIF
____Drip irrigation
____Remove weeds
____Recycle water
____Use chemical pesticides
____Soil testing
____Water testing
____Use disease test kits
____Pest resistant varieties
____Cover floor with weed cloth
____Preventative pesticide treatment

____Release predators, parasites, nematodes
____Spray insecticides on floor/benches
____Use pesticides less toxic to beneficials
____Use pesticides with short residual activity
____Use microbial biocontrol (fungi, bacteria)
____Other (specify):__________________
____Send plants out for disease testing

For this survey:

IPM (Integrated Pest Management) is defined as using multiple tactics (scouting, cultural practices, biological control, pesticides, etc.) to manage pests while minimizing chemical pesticide use.

Conventional Pest Control is defined as using chemical pesticides as the primary method to manage pests and diseases.

9) What kind of production system best describes your operation?

IPM _______ Conventional Control _______Other (specify):____________________

10) Compared to Conventional Control, how do you think IPM performs?

	Worse	The Same	Better
Effectiveness			
Cost			
Reliability			
Uniformity			
Consumer approval			
Easy to use			

11) What challenges hinder your greater adoption of IPM? Rank each as follows:
1 = a little hindering; **2** = moderately hindering; **3** = greatly hindering.

____Hard-to-control insect/mite pests
____Pesticide-resistant insects & diseases
____Lack of knowledge about alternatives
____Lack of workers skilled in IPM
____Biological control is too expensive
____Lack of knowledge of pest biology
____Selective pesticides are expensive
____Lack of time to implement IPM
____Consumer intolerance for infested plants
____ IPM in general is too expensive
____Owner/manager won't let me
____Consumers will not pay higher price for "greener" product
____Hard-to-control diseases
____Hard-to-control weeds
____Unreliable biocontrols
____Ineffective pesticides
____Quarantine regulations
____Lack of confidence in IPM
____Pest diagnosis & ID
____Gives unreliable results
____ Plants bought in are infested
____IPM supplies not available

____Other:____________________________

12) What limits your use of biological control agents (parasites, predators, microbials, etc.)? Rank each as follows: **1** = a little limiting; **2** = moderately limiting; 3 = very limiting.

____There are no limits **(if you select this, select no others)**
____Can't risk economic loss
____Poor shelf life
____Biological control is too expensive
____Lack confidence that biologicals work
____Consumer intolerance for plants with visible natural enemies
____Lack of knowledge about how or when to use them
____Low quality of biological control agents purchased
____Not compatible with chemical pesticides
____Consumer intolerance for plants with visible pest insects
____Quarantine laws require pesticide treatment
____Biocontrol agents are not readily available
____Don't know how to reduce chemical pesticide use.
____Other: ________________________________
____Biological control is not reliable
____Don't know where to order them
____Owner/manager won't allow their use

13) How can Extension or State Dept. of Agriculture personnel best help you adopt more IPM? Rank each as follows: **1** = a little helpful; **2** = moderately helpful; **3** = very helpful.

____Provide regular site visits by specialists
____Prepare/circulate fact sheets on key pests
____Hold educational workshops for growers
____Crop insurance if I use biological control
____Establish a professional IPM advising service
____Conduct efficacy trials and publish the results
____Establish regional computer links to communicate problems & solutions
____Establish regional newsletter to communicate problems & solutions
____Establish consumer education about benefits of IPM
____Other:____
____Set up demonstration projects
____Set up IPM certification prog.
____Incentive programs to use IPM

14) What research/information is needed to help you adopt more IPM?
Rank items below as follows: **1**= low need; **2**= moderate need; **3**= great need.

____Biological control guidelines
____Pesticide/biocontrol compatibility
____Local guidelines for IPM
____Spray application methods
____Action thresholds (pest levels at which action should be taken)
____Cost/benefit analyses for production
____Computer-based pest management programs
____Other:____
____Other:____
____Scouting methods
____Pest-resistant plant cultivars
____Pest/disease biology
____Degree day monitoring

APPENDIX II: FOUR CATEGORIES OF IPM PRACTICES

MONITORING:
Sticky cards
Indicator plants
Regular scouting
Hire commercial scout
Use deg. days to track pests
Foliar testing

PEST IDENTIFICATION:
Identify pests/diseases yourself
Professional insect/disease ID
Use disease test kits
Send plants out for disease testing

PREVENTION:
Screen vents
Crop rotation
Inspect new plant shipments
Disinfect growing areas
Sanitize pots or use new ones
Sanitize soil or use new soil
Reemay plant covering
Culture indexed plants
Fallow crop space
Use DIF
Drip irrigation
Remove weeds
Recycle water
Soil testing
Water testing
Pest resistant varieties
Cover floor with weed cloth

CONTROL:
Rotate pesticide classes
Release predators, parasites, nematodes
Spray insecticides on floor/benches
Use pesticides less toxic to beneficial
Use pesticides with short residual activity
Use microbial biocontrol (fungi, bacteria)
Spot pesticide treatment
Use chemical pesticides
Preventative pesticide treatment

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