Adoption and Impacts of Integrated Pest Management for Cambodian Rice Farmers

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ACADEMIC ABSTRACT

This study evaluates the adoption and impacts of Integrated Pest Management (IPM) for rice in four provinces in Cambodia. Farmers are considered high adopters if they used two non-pesticide or minimal-pesticide practices to control rice insect, disease, weed, or rodent pests in the last twelve months; farmers are considered low adopters if they used one practice; farmers are considered non-adopters if they used zero practices. Proportion and characteristics of adopters, frequency and type of IPM practices, and scope of IPM training in the region are discovered. Determinants of adoption are analyzed using multinomial logistic regression. The effect of adoption on level of pesticide use on rice is analyzed using linear regression.

Out of 394 farmers surveyed, 40 (10.15%) were found to be high adopters, 228 (57.86%) were found to be low adopters, and 126 (31.97%) were found to be non-adopters of IPM. IPM practices currently include mostly hand-weeding and no spray for 40 days; few other practices were adopted. 22.59% of farmers in our study have received training on IPM.

Greater experience in rice cultivation and considering extension as a top source of agricultural knowledge were identified as significant factors that, all other factors held constant, increase the likelihood of both low and high levels of adoption. Considering media as a top source of agricultural knowledge also increases the likelihood of high adoption. Greater number of household members who are able to work and considering input suppliers as a top source of agricultural knowledge were identified as significant factors that, all other factors held constant, decrease the likelihood of low and high levels of adoption.

Adoption of IPM was not found to have a statistically significantly effect on the number of pesticide applications on rice.

Our study reveals the need for increased training on rice IPM in Cambodia, and the need for future IPM education to focus on reducing pesticide use.

Adoption and Impacts of Integrated Pest Management for Cambodian Rice Farmers

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GENERAL AUDIENCE ABSTRACT

This study evaluates the adoption and impacts of Integrated Pest Management (IPM) for rice in four provinces in Cambodia. IPM is an ecologically-friendly pest management philosophy that offers alternatives to reliance on harmful chemical pesticides.

Farmers are divided into groups of high adopters, low adopters, and non-adopters depending on the number of IPM practices used. Proportion and characteristics of adopters, frequency and type of IPM practices, and scope of IPM training in the region are discovered. Determinants of adoption and the effect of adoption on level of pesticide use on rice are analyzed using econometric analysis.

Out of 394 farmers surveyed, 40 (10.15%) were found to be high adopters, 228 (57.86%) were found to be low adopters, and 126 (31.97%) were found to be non-adopters of IPM. Adopters primarily use only two types of IPM practices. Less than one-quarter of farmers in our study have received training on IPM.

Farmers who have more years of experience in rice cultivation, and farmers who consider agricultural extension a top source of agricultural information are more likely to adopt IPM. Farmers who have more family members who are able to work, and farmers who consider input suppliers a top source of agricultural information are less likely to adopt IPM.

Adoption of IPM was not found to meaningfully influence the number of pesticide applications on rice.

Our study reveals the need for increased training on rice IPM in Cambodia, and the need for future IPM education to focus on reducing pesticide use.

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[1] EPIC is a five-year rice improvement program with a research period of October 2015 through September 2019.

[2] Feed the Future is the U.S. Government's global hunger and food security initiative aimed at eliminating global hunger. Cambodia is one of the nineteen target countries where Feed the Future is focusing to provide change and lasting impact.

[3] The IPM Innovation Lab (IPM IL), formerly the IPM CRSP, was one of nine collaborative research labs set up by USAID after Title XII legislation was passed in 1975. The IPM aims to disperse IPM throughout sixteen countries including Cambodia, expand research and education for IPM, and build capacity in local and national institutions.

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1. Chapter 1: Introduction

1.1. Problem Statement

Most Cambodians depend on rice production for their livelihoods, yet many farmers are poor, female farmers are disenfranchised, pesticide poisoning is rampant, and the environment is negatively affected. Despite having a comparative advantage in agricultural land area, Rice yields in Cambodia are among the lowest in Southeast Asia (FAO, 2017). Farm sizes are small, with a national average of only 1.2 hectares, and most farmers produce at a subsistence level - only 40% produce a surplus to bring to market (USDA FAS, 2010). One in five rural Cambodians live below the nationally measured poverty line (UN Statistics Division, 2015).

Insect, disease, weed, and rodent pests contribute to rice yield loss. According to the International Rice Research Institute (IRRI (b), no date), 37% of Cambodian rice crop is lost every year due to pests. Insects are of particular importance on tropical rice farms (Reissig et al, 1986). Weeds can cause anywhere from 27-60% of a loss in yield (Quijano-Guerta, 2015), and can destroy the entire crop in some extreme cases (Reissig et al, 1986). IRRI cites rats as causing an average of 5-10% annual yield loss for Asian rice farmers, while Reissig et al. (1986) estimates that rats can cause yield losses of anywhere from 5-60%. Cambodian farmers are sensitive to these outbreaks, without many resources to fight against them (Open Development Initiative, 2015).

To prevent yield loss associated with pests, Cambodian farmers regularly turn to chemical pesticides. Types of pesticides used to control rice insect, disease, weed, and rodent pests are known as insecticides, fungicides, herbicides, and rodenticides, respectively. However, in the Cambodian pesticide market it is common to find high-toxicity chemicals which are banned or restricted in more developed countries (Ecobichon, 2001). Imported pesticides with packaging labeled in other languages leads to misapplication. Lack of enforcement on the regulations regarding proper pesticide usage further contributes to misuse and poisoning (Quijano-Guerta, 2015). Jensen et al (2011) and Schreinemachers (2017) found high rates of pesticide poisoning among Cambodian farmers.

In addition to the negative effect on human health, pesticides harm the environment. Pesticide resistance occurs when target pests develop resistance to certain types of pesticides due to repeated use or over-application (El Sebae, 1993). Pesticide runoff, erosion, and leaching from pesticides pollute the surrounding air, water, soil, and crops with toxic buildup and cause damage to non-target organisms (Reissig et al, 1986; Parris and Yokoi, 2003; El Sebae, 1993). Overuse of pesticides can have a reverse effect; pest outbreaks occur when beneficial insects, or natural enemies of rice pests, are killed along with rice pests as a result of the application of chemical pesticides (IRRI (b), no date). This effect is known to spur infestations of pests such as brown planthopper and stem borers (IRRI (b), no date; Quijano-Guerta, 2015).

Though females make up more than half of the agricultural workforce in Cambodia, women are largely disadvantaged when it comes to farming (Quijano-Guerta, 2015). The women’s literacy rate is 11% lower than it is for men, female farmers receive less agricultural training, and there is a void of female extension agents (Quijano-Guerta, 2015). Women made up less than 20% of on-farm extension training participants in 1999, and in 2010, only 10% of farmers receiving extension information were women (Quijano-Guerta, 2015).

Cambodia can find its comparative advantage in the international rice market by focusing on high quality rice. However, in order to meet standards such as the Sustainable Rice Platform and maintain a steady supply of high-quality rice for export, a reduction in pesticide levels must be obtained and a consistent pest management strategy employed (Quijano-Guerta, 2015; Matsukawa, 2016).

Alternative practices, collectively termed integrated pest management (IPM), can be used to manage pests while protecting human and environmental health (Quijano-Guerta, 2015). Integrated pest management is a philosophy of managing pests that “emphasizes using increased information to make pest management decisions and integrating those decisions into ecologically and economically sound production systems” (Norton, 2005, p.4). IPM combines the use of cultural, biological, and chemical methods to maintain pests within an economically sustainable level (Reissig et al, 1986; Quijano-Guerta, 2015; Norton, 2005). The use of IPM for rice in Cambodia can reduce yield losses while mitigating the problems of pesticide resistance, loss of beneficial insects, environmental pollution, harm to humans and non-target organisms, and gender inequality in pest management (Reissig et al, 1986; Quijano-Guerta, 2015).

Controlling rice pests through IPM has the potential to increase farmer incomes and improve Cambodians’ livelihoods by capacitating women, reducing yield losses, and minimizing externalities. Additionally, IPM practices could add value and contribute to higher quality rice, which would help the government achieve its goal of becoming a major rice exporting nation (Quijano-Guerta, 2015; USDA FAS, 2010).

Though the potential benefits of using IPM are enormous, farmers lack understanding of the techniques and benefits of the technology, hence the use of IPM for rice throughout developing countries in Asia (excepting Indonesia, the Philippines, and China), is infrequent (Reissig et al, 1986; Alam et al, 2016; Norton, 2005). Current adoption of rice IPM practices in Cambodia is unknown.

A program led by IRRI for the Feed the Future Collaborative Research on Integrated Pest Management Innovation Lab intends to fill the pest management gap in Cambodia by creating a rice IPM package specific for the Cambodian ecosystem, which will then be distributed throughout the country. This program is called Development of Ecologically based Participatory

Integrated Pest Management Package for Rice in Cambodia (EPIC). The region of focus is four provinces: Takeo, Prey Veng, Kampong Thom, and Battambang. From 2015 to 2019, EPIC will develop an ecologically-based IPM rice package, then validate, implement, and promote the package throughout the region of interest.

It is essential to create a baseline for the EPIC program. This baseline will establish a point of reference to highlight the changes that occur over the course of the project. Quijano-Guerta (2015, p.19) states, “Changes in the levels of farmers’ IPM knowledge, attitude, and practice, together with reported field productivity and profitability before and after the interventions, will serve as measures of project impact.” A baseline will provide up-to-date information on rice production and pest management practices in the region.

First, before distributing the rice IPM package for Cambodia, the extent of IPM adoption in the region must be discovered. The proportion of adopters in the region should be discovered, along with the frequency and type of IPM practices being used. Adoption in this study will be defined as the use of one or more cultural or biological methods to control pests. Characteristics of adopters and non-adopters, i.e. gender of primary farmer, years of experience in rice cultivation, hectares of rice cultivated, etc., should be discovered to gain perspective on the average farmer in the region. Finally, the scope of IPM training should be studied, including the proportion of households who have received IPM training, the number of IPM trainings received by adopters and by non-adopters, and the source of IPM trainings.

Second, the determinants of rice IPM adoption in the region should be analyzed in order to provide EPIC with information about which factors predict adoption. Knowing which farmers are most likely to adopt IPM will assist EPIC in eventual achievement of maximum adoption in the region. EPIC can increase adoption by targeting promotion of the IPM package towards farmers who are most likely to adopt. Additionally, identification of factors that may cause farmers to be more resistant to adoption will demonstrate potential roadblocks to wider adoption. Several factors should be examined in more detail. EPIC desires to learn how gender differences in division of labor and decision-making affect adoption of pest management; thus, the effect of gender on the likelihood of adoption is important. EPIC plans to promote the IPM package through educational programs and trainings; the effect of IPM training on the likelihood of adoption should be discovered. Various mediums including video and audio, community leaders, and input supply sources will be used to distribute the IPM package; the effect of agricultural knowledge source (i.e. media, extension, input suppliers, and/or community) on the likelihood of adoption will be of interest. Any other leading determinants of adoption should be discovered as well.

Third, the effect of adoption on level of pesticide use should be analyzed in order to assess the potential for IPM to reduce harm to human health and the environment in Cambodia.

The objectives for this study are outlined in the follow section.

1.2. Objectives

I. The first objective for this study is to establish a baseline the EPIC project. The following foci will be explored: the proportion of adopters in the region; characteristics of adopters and non-adopters; frequency and type of IPM practices adopted; and scope of IPM training in the region.

II. The second objective is to analyze the determinants of adoption. The following factors in particular will be examined: gender, IPM training, agricultural knowledge source, and any other leading determinants of adoption.

III. The third objective is to analyze the effect of adoption on level of pesticide use.

1.3. Organization of Thesis

This thesis is organized into five chapters: The second chapter provides a review of the literature related to the agricultural history of Cambodia, the rice sector in Cambodia, rice pests, and forms of pest management. The third chapter provides a conceptual framework for the models employed, details the survey design and data collection methods, and describes the empirical models, variables, and expectations. The fourth chapter presents and discusses the results for each objective. The fifth chapter offers concluding remarks.

2. Chapter 2: Background and Literature Review

2.1. Background

2.1.1. Geographic, Political, and Economic Overview of Cambodia

Cambodia is located in Southeastern Asia between Thailand to the west and north, Vietnam to the east and south, Laos to the north, and the Gulf of Thailand to the southwest. Cambodia has a tropical climate, with a rainy season from May to November and a dry season from December to April. Flat, low plains make up most of the land, with mountains in the southwest and northern parts of the country (US CIA, 2016). Thirty-two percent of the land is used for agricultural purposes (US CIA, 2016). Most of the country's 15.9 million citizens live in the capital city Phnom Penh in the southeast, in the rural areas surrounding the capital, or around the Tonle Sap and Mekong Rivers (US CIA, 2016). About half of the population is under 25 years of age, as of 2016 (US CIA, 2016).

Throughout the twentieth century, colonial rule, communism, socialism, civil war, and international intervention marked the major political transitions in Cambodia. A short period of freedom followed colonial rule when independence from France was gained in 1953 (US CIA, 2016). The Khmer Rouge regime captured capital city Phnom Penh in 1975 under Pol Pot (US CIA, 2016; Chhair and Ung, 2013). Private capital was destroyed, urbanites were forced out of cities and towns, religion was suppressed, civilians were killed, foreigners were expelled, and almost all citizens were required to work on state-owned agricultural land (Kiernan, 1996; Curtis, 1998; Chhair and Ung, 2013). Eventually an estimated 1.5 million citizens died from hardship and genocide during the Khmer Rouge period (US CIA, 2016). A coup by the Vietnamese in 1978 led only to civil war, which lasted until the United Nations intervened in the early 1990's and Cambodia finally transitioned to a market economy (US CIA, 2016; Chhair and

Ung, 2013). The government has since mostly stabilized as a democratic state, but is still considered highly corrupt, being marked by violence in political interventions and the rampant existence of human trafficking (US CIA, 2016; Transparency International, 2016).

Despite numerous hardships, Cambodia has recently exhibited significant economic growth after a century of being characterized by instability. The economy managed a strong growth rate of 8% on average in the first decade of the 21st century, with most of the growth taking place in the agricultural, tourism, garment, and construction and real estate sectors (US CIA, 2016). The agricultural sector makes up about a third of the nation's production (US CIA, 2016). Seventy-one percent of the population depends on agriculture as a source of income, with rice as the primary agricultural product (USDA FAS, 2010; US CIA, 2016). The poverty rate was cut 75% from 1994 to 2011; however, Cambodia remains one of the poorest countries in Asia. As of 2011, 10.1% of its citizens live below the world poverty level of $1.25 PPP per day, and GNI per capita is only $2,230 PPP (UN Statistics Division, 2015; CGIAR, no date).

2.1.2. History of Rice Sector in Cambodia

Rice has been cultivated in Cambodia for at least 2,000 years since its introduction from trade routes with India (Helmers, 1997). Farmers adapted rice production technologies to suit their needs, developed production systems for various ecosystems, and bred different varieties (Helmers, 1997). Rice was at the center of the economy from the 9th to the 14th centuries AD during the period of the Angkor kingdom, which was based around the Tonle Sap Lake region (Helmers, 1997). During this period, land farmed for rice increased and irrigation technology expanded (Helmers, 1997). After the fall of the Angkor Empire, the rice industry lost power (Helmers, 1997). Throughout this precolonial age, rural needs were generally met adequately, though unpredictability of rains, taxes on rice, and intermittent wars were underlying threats to food security (Helmers, 1997).

In the early 20th century, the French responded to frequent famines by devising an agricultural development policy to boost exports of rice and other products (Helmers, 1997). The French plan divided rice production into two subsectors: one of large plantations using modern methods in Battambang province, which were controlled by colonists and benefitted from infrastructure and research stations; and one of smallholdings throughout the country farmed by rural peasants, who used traditional methods and were heavily taxed by the French (Helmers, 1997). Because the government did not invest in the peasant subsector, yields remained around 1 ton per hectare during the colonial period, and education and training were minimal (Helmers, 1997).

Education, rice research, and rice production expanded in the period following independence from France, but prices paid to farmers were low and there was little advancement in new production technology (Helmers, 1997). Then, before the Khmer Rouge came to power, the Second Indochina War "devastated rice production, the economy, and the livelihoods of the rural people" (Helmers, 1997, p.5). Area of rice farmed decreased by 77% and rice production dropped by 84% between 1970 and 1974 (Helmers, 1997). Afterwards, the Khmer Rouge regime attempted to increase rice production by collectivizing rice farms and creating irrigation systems. However, the irrigation systems failed, skilled labor disappeared, and research stations were destroyed or abandoned; in all, rice production development during this time was "almost a total failure" (Helmers, 1997, p.6). Rice production finally increased again in the 1980's, but food insecurity and poverty remained rampant (Helmers, 1997). Eventually, when the market economy emerged in 1989, land was privatized equitably among community members. In the early 1990's, rice made up 17% of national GDP (Helmers, 1997).

2.1.3. Present-Day Rice Sector and Contribution to Rural Life

Currently, agriculture is a priority to national development. Of Cambodia's 15.7 million inhabitants, rice contributes to household income for approximately 12.5 million people (Quijano-Guerta, 2015). Improved access to inputs since the mid-1990's has increased rice production; annual production was recorded at 9.324 million tons in 2014 (FAO, 2017). Rice exports rose in the late 20th century after decades of relying on imports (CGIAR, no date). Now, the Cambodian government plans to double rice production and expand exports to become a major rice export nation; a new "White Gold" policy was recently adopted to bring new technologies and better agricultural practices (USDA FAS, 2010; Open Development Initiative, 2015; CGIAR, no date).

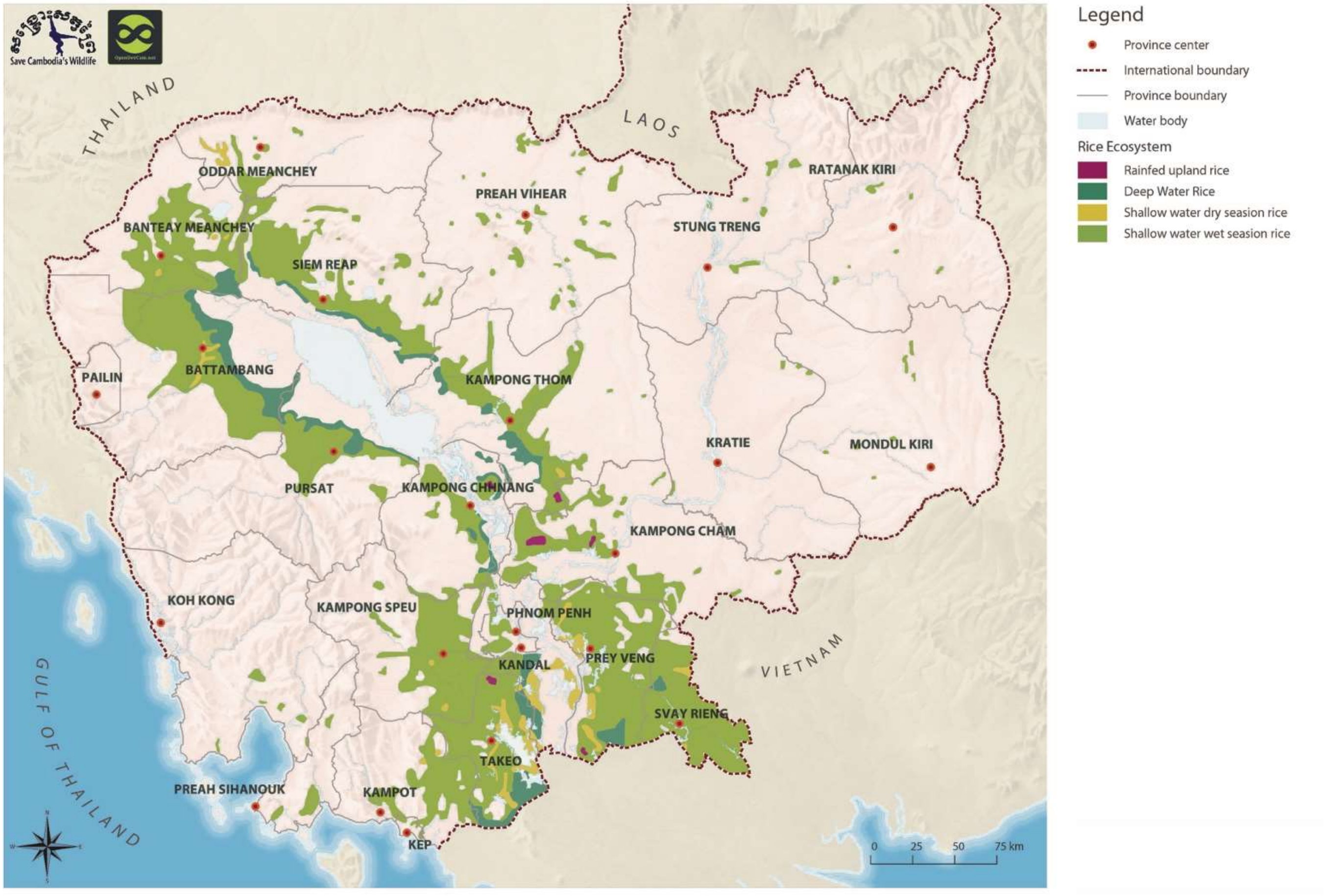
Eighty percent of Cambodians live in rural areas (USDA FAS, 2010). Rural households are made up of 5.5 people on average, have an average of 2.9 adult laborers, and about 20% are headed by a female (Helmers, 1997). Males and females in rural areas only have an average of 4.4 years and 2.2 years of education, respectively (Helmers, 1997). Eighty-two percent of rural Cambodians participate in agriculture, forestry, and fishing activities including rice production, production of other crops, raising livestock, hunting and gathering, and fishing (Helmers, 1997). These rural agricultural households also participate in wage labor and small business (Helmers, 1997). Most Cambodians own their own farmland though legal land titling is rare (Helmers, 1997). Farm sizes range from 1.0 to 4.0 hectares in rural areas including Takeo and Prey Veng provinces, with a national average of 1.2 hectares (Helmers, 1997; USDA FAS, 2010).

Rice is the most important crop for rural citizens in Cambodia and is the staple food in the region (Helmers, 1997). Rice contributes 65–75% to the population's daily caloric intake, providing protein and carbohydrates (the primary source of protein is fish) (CGIAR, no date.; Helmers, 2017). On average, rice comprises 44% of household income for rural citizens (Quijano-Guerta, 2015; USDA FAS, 2010). However, as of 2012, 20.8% of the rural population lives below the nationally measured poverty line (UN Statistics Division, 2015). Out of the entire population, 14.2% of people were undernourished as of 2015, and 29% of children under the age of five were moderately or severely underweight as of 2010 (UN Statistics Division, 2015).

Almost all of Cambodian rice is cultivated in the wet season, from May to January; less than 10% is cultivated in the dry season (Helmers, 1997). The four ecosystems in which rice is grown in Cambodia are rainfed lowland, rainfed upland, deep-water, and irrigated (CGIAR, no date). Rainfed lowland is the dominant production method, with 74% of the total land cultivated for rice taking place on low-lying plains throughout the country (Quijano-Guerta, 2015; Helmers, 1997; CGIAR, no date). The largest concentrations of rainfed lowland are around Tonle Sap, the Tonle-Basaac River, and the Mekong River (see Figure 1) (Quijano-Guerta, 2015; Helmers, 1997; CGIAR, no date; Open Development Initiative, 2015). Twenty percent of the rice cultivated in Cambodia is dry season irrigated rice, which is grown predominantly in the Takeo, Kandal, Prey Veng, and Kampong Cham provinces (see Figure 2.1) (Quijano-Guerta, 2015; Javier, 1997). Demand for labor is highest during the wet season, and households frequently hire labor to meet demand (Helmers, 1997). On average, total labor person-days per hectare range from 85 to 114 days, with a high standard deviation (Helmers, 1997).

In developing countries like Cambodia, gender affects various agricultural issues including access to resources (such as land, labor, education, and credit), the way that individuals spend their time, and opportunities (OIRED (b), no date). Women play an important role in household finances and decision-making, and manual pest management activities such as weeding and rodent control are performed by women (OIRED (b), no date; Feed the Future (2), no date; Quijano-Guerta, 2015). Women account for 60-65% of Cambodian rice farm labor, presiding over tasks such as transplanting and general crop husbandry, and leave more strenuous tasks, such as land preparation, to men; both men and women carry out the harvest (Helmers, 1997). Unfortunately, women are paid an average of 30% less to do the same work as men in Cambodia (Feed the Future (2), n.d.). In addition, men have disproportionately more access to agricultural information and training despite the fact that 62% of Cambodian agricultural workers are women (Quijano-Guerta, 2015).

Figure 2.1: Rice Ecosystem Map for Cambodia



Open Development Initiative, 2015

Seventy-five percent of Cambodia's 3.7 million hectares of agricultural land is devoted to rice production, but rice yields, share of rice exports in total rice production, and total rice exports are lower than most other countries in Southeast Asia (FAO, 2014; USDA FAS, 2010; Inserey, K., 2013; Yu, B., Diao, X., 2011; Workman, D., 2016). Despite a comparative advantage in land and labor abundance, Cambodia has one of the lowest productions of rice paddy per hectare compared to its neighbors (Sophal, C., 2002). Average per hectare rice yield in 2014 was 3.26 tons in Cambodia, compared with 4.18 tons in Laos, 3.89 in Myanmar, and 5.75 tons in Vietnam (See Table 2.1) (FAO, 2017).

Table 2.1 Rice Paddy Yield in Southeast Asia (2014)

Area	Yield (t/ha)	Area harvested (ha)	Production (t)
Cambodia	3.26[3]	2,856,001[2]	9,324,000[1]
Laos	4.18[3]	957,836[1]	4,002,425[1]
Myanmar	3.89[3]	6,790,000[1]	26,423,300[1]
Thailand	3.06[3]	10,664,923[1]	32,620,160[1]
Vietnam	5.75[3]	7,816,476[1]	44,974,206[1]
Southeast Asia Region[a]	4.34[3]	48,341,877	209,893,536

[1]Official Data; [2]FAO Data; [3]Calculated Data

[a]Includes Brunei, Cambodia, Laos, Indonesia, Malaysia, Myanmar, Philippines, Thailand, Timor-Lest, and Vietnam

Source: FAO, 2017

Rice productivity per hectare is low due to a number of factors. Farmers often cultivate only one rice crop per year, use of improved seeds is limited, improved modern methods (such as fertilizer and farm mechanization) are not widely used, skills and knowledge are underdeveloped due to limited extension services, and investment is inhibited by lack of access to formal credit markets (CGIAR, no date; FAO, 2014). Furthermore, underdeveloped transportation and infrastructure, and thus limited access to markets, weakens the rice sector (CGIAR, no date; Open Development Initiative, 2015). In addition, soils are poor, rice crops are vulnerable to weather and climate disasters, farmers are not able to spread risk through formal insurance markets, and low investment in agricultural research restricts technological solutions (Javier, 1997; FAO, 2014; CGIAR, no date). Further, insufficient extension services and low education result in limited training and poor farming skills (FAO, 2014; CGIAR, no date). Finally, yields are reduced due to insect, disease, weed, rodent, and other pests.

2.2. Rice Pests and Management of Pests

2.2.1. Rice Pests

Rice Market Monitor (2009) estimates that pests and weather contribute to a total loss of up to five to ten percent of annual fresh rice paddy yield in Cambodia, but according to the International Rice Research Institute (IRRI (b), no date), pests and diseases destroy an average of

37% of the rice crop annually. Rice cultivated during the dry and wet seasons share similar pest problems (Javier, 1997). Matsukawa (2016) found insect pests present in 94% of fields in the study area in Takeo province, and diseases in 61.8% of the fields. Weeds were found to be present in all Prey Veng study area fields, insects in 97% of fields, and diseases in 48.5% of fields (Matsukawa, 2016).

Insects causing damage to rainfed lowland and irrigated rice in Cambodia include stemborer, brown planthopper, gall midge, leaf-folder, and caseworm (Javier, 1997; Catindig, n.d.; Catindig and Heong, n.d.; see photos in Appendix A.1. Rice Pest Scientific Names and Photos). Other insect pests in Cambodia include green leafhopper, thrips, grasshopper, rice bug, and army worm (Javier, 1997; Catindig, n.d.; see photos in Appendix A.1. Rice Pest Scientific Names and Photos). Various types of stemborers can cause anywhere from 20% yield loss to loss of the entire crop (Catindig and Heong, n.d.). The brown planthopper can cause up to 100% crop loss at high levels of infestation (Catindig, n.d.). Gall midge can cause yield losses of 30-40% in parts of South Asia (Catindig, n.d.). Leaf-folders can cause yield loss when infestation occurs at the reproductive phase of the rice crop (Catindig, n.d.). Caseworms can cause defoliation that stunts plant growth and kill rice plants (Catindig, n.d.).

In rainfed lowland rice, brown spot, a fungal disease, is the most common disease, with highest incidence in Kampong Cham, Kampong Speu, Prey Veng, and Takeo provinces (Jahn, 1997). Brown spot causes 5% yield loss on average in Southeast Asia, with some yield losses up to 45% (Sparks, Castilla, and Vera Cruz, n.d.). Tungro, a virus transmitted by green leafhoppers, is the most common disease in Cambodian irrigated rice and, according to Sparks, Castilla, and Vera Cruz (n.d.), one of the most destructive rice diseases in the area. According to Sparks, Castilla, and Vera Cruz (n.d.), rice fields infected with Tungro in early growth stages could be susceptible to yield losses of up to 100%. Other diseases affecting rice in Cambodia include bacterial blight, sheath rot, and sheath blight (Javier, 1997). Bacterial blight can cause yield loss up to 70%, Sheath rot has caused yield losses from 30-80% in South Asia, and Sheath blight can cause up to 6% yield loss in tropical Asia (Vera Cruz, n.d.; Sparks, Castilla, and Vera Cruz, n.d.).

Weed management is a major problem in the rain-fed lowlands of Cambodia due to uncontrollable water levels in the fields (Jahn et al. 1997). Weeds can cause anywhere from 27-60% of a loss in yield (Quijano-Guerta, 2015), and can destroy the entire crop in some extreme cases (Reissig et al, 1986). Broadleaf weeds, grasses, and sedges, the most common of which is dirty dora, all interrupt rainfed lowland rice in Cambodia (Jahn, 1997). Weeds thrive when standing water is not maintained in rice fields; this is more of a problem for rainfed lowland rice than for irrigated rice (Javier, 1997). Weeds contribute to yield loss by competing with rice plants for sunlight, nutrients, and water (IRRI (a), no date). They also provide an environment for insect pests and rats to thrive, exact higher labor costs, can decrease the selling price of rice, and some can even harbor rice pathogens (Reissig et al, 1986; IRRI (a), no date; Jahn, 1997).

Definitive data on rodent yield loss is difficult to come across, but IRRI cites rats as causing an average of 5-10% annual yield loss for Asian rice farmers, and Reissig et al. (1986) estimates that rats can cause yield losses of anywhere from 5 to 60% (Quijano-Guerta, 2015; IRRI (b), no date).

Other pests affecting rice yields include birds, crabs, and snails. Jahn (1997) lists birds as a major animal pest for dry season rice in Cambodia. Javier (1997) explains that birds eat seeds and ripening grain and crabs damage seedlings. The golden apple snail “has the potential to inflict tremendous damage” to dry season rice in Cambodia (Jahn, 1997, p. 89). Transplanting older rice seedlings can help reduce damage from snails (Jahn, 1997).

2.2.2. Pest Management

2.2.2.1. Pesticides

Cambodian farmers are sensitive to pest outbreaks, which have been more frequent due to developments in rice production technology such as high-yielding varieties (Open Development Initiative, 2015; Reissig et al, 1986). Yield loss can be prevented if damage from pests is managed, but farmers lack resources to fight against pests. Cambodian farmers frequently turn to chemical pesticides; up to two-thirds of Cambodian farmers use pesticides to control pest populations (CEDAC, 2000, cited by EJF, 2002). High-yielding varieties of rice have increased rice production and enabled greater investment in pesticides (Reissig et al, 1986). Between 2006 and 2010, the value of pesticides imported into Cambodia increased 285 times, with a total of US$629,186,000 worth of pesticides imported into Cambodia in 2010 (FAO 2012, cited from Quijano-Guerta, 2015).

Insecticides and rodenticides are the most commonly used pesticides, followed by herbicides (Jahn, 1997). Use of fungicides is rare (Jahn, 1997). There are at least thirty different varieties of insecticides used by Cambodian farmers (Jahn, 1997). Jahn (1997) found methyl parathion to be the most common pesticide used in most provinces. Pesticides are applied more extensively in the dry season, by 40-100% of farmers, than in the wet season, in which 8-50% of farmers use pesticides (Jahn, 1997). Men almost always apply the pesticides, with 71-100% of the applicators being males (Jahn, 1997). However, women may apply pesticides during seasons of labor shortage (Quijano-Guerta, 2015).

Though pesticides are somewhat effective, they are frequently misused, with detrimental results to farmer health, non-target organisms, the environment, and the natural balance of pests in the rice ecosystem (Reissig et al, 1986). Many of the pesticides used in Cambodia are classified as Category I, the most hazardous class of pesticides labeled by the World Health Organization (WHO) (Jahn, 1997; Jensen, 2011; EJF, 2002). Though these pesticides should not be used, they persist because safety information and legislations are lacking, and pesticide regulations are not enforced (Jahn, 1997; Quijano-Guerta, 2015; Jensen, 2011; Ecobichon, 2001; EJF, 2002; El Sebae). Inadequate training, proper equipment, disposal methods, quality control, and knowledge about the dangers of risks of pesticide exposure further lead to pesticide misuse (Open Development Initiative, 2015; Schreinemachers, 2017; El Sebae).

Because the majority of pesticides on the Cambodian market are imported from China, Vietnam, or Thailand and are labeled in foreign languages, farmers cannot understand the instructions and often use the products incorrectly or mix several pesticides together regardless of type (Quijano-Guerta, 2015; El Sebae, 1993; Matsukawa, 2016; EJF, 2002). Matsukawa (2016) found that farmers in Takeo and Prey Veng provinces mix on average 13.4 and 12.8 pesticides among 5.0 and 4.5 applications per field, respectively. Schreinemachers (2017) found that Cambodian farmers mix 3.7 pesticides together on average. Jensen et al (2011) found that Cambodian aquatic farmers mixed between four and six pesticides in a single application.

Further, Matsukawa (2016) found that farmers in Takeo and Prey Veng provinces apply pesticides simply due to the presence of pests, regardless of level of severity, and Schreinemachers (2017) noted that Southeast Asian farmers could rarely distinguish between beneficial insects and pests. EJF (2002) noted that insecticides are often applied at the wrong time or to target the wrong pest. One study showed some Cambodian farmers falsely believe that pesticides can enhance rice growth, and another showed that 42% of Cambodian pesticide applicators believed herbicides were not harmful to humans (Matsukawa, 2016; Schreinemachers, 2017).

Pesticides can poison humans by being absorbed through the skin or inhaled; they can cause irritations to humans and can be lethal (Reissig et al, 1986). Globally, WHO estimated a total of 3 million cases of severe pesticide poisonings in 1990 (Ecobichon, 2001). WHO attributes 30% of global suicides to pesticide poisoning, which commonly occur in rural agricultural areas in developing countries (WHO, 2017). Non-lethal pesticide poisoning can cause harmful reproductive, neurological, psychological, and cytotoxic effects (El Sebae, 1993). Environmental Justice Foundation cited a report from 2000 by the FAO Community IPM program which found that 88% of Cambodian farmers who sprayed pesticides had experienced pesticide poisoning (Sodavy, et al, 2000, cited by EJF, 2002). Jensen et al (2011) similarly found that 88% of Cambodian aquatic farmers who sprayed pesticides had experienced poisoning in the previous month. Schreinemachers (2017) found that up to 25% of pesticide applicators in Cambodia had experienced serious poisoning symptoms including muscle twitching, vomiting, and chest discomfort. Children may also be affected by pesticide side effects; almost half of Cambodians farmers surveyed allowed their children to apply pesticides (EJF, 2002).

In Cambodia, 24% of pesticide applicators were found to be female (Schreinemachers, 2017). However, the prevailing gender expectation is that the job of spraying pesticides is for men (Schreinemachers, 2017). Schreinemachers (2017) found that female applicators reported 3.2 more poisoning symptoms than men; Schreinemachers presumes this is because females were more observant of their health.

Overuse of pesticides can disturb the natural balance between rice pests and their natural enemies (called beneficial insects), leading to outbreaks of destructive pests such as brown planthopper and stemborers (IRRI (b), no date; Quijano-Guerta, 2015; Jahn, 1997; El Sebae, 1993). Use of insecticide early in the rice-growing season can cause disruptions in the natural ecological balance that kill beneficial insects and lead to an emergence of secondary pests such as planthoppers (Catindig, n.d.; IRRI (b), no date; El Sebae, 1993). Extended or concentrated use of pesticides can also lead to pesticide resistance, where pests develop resistance to certain types or chemical groups of pesticides (El Sebae, 1993). This can occur within insects, snails, mites, ticks, fungi, bacteria, rodents, and weeds (El Sebae, 1993). When pesticide resistance transpires, farmers use higher volumes of pesticides in order to reduce damage to the crop, repeating a cycle of pesticide resistance and even higher volumes of chemicals (EFJ, 2002).

Environmental pollution occurs from pesticide runoff, residues, erosion, leaching, and vaporization (El Sebae, 1993; Parris and Yokoi, 2003). Pesticides pollute the air, water, soil, livestock, wildlife, and non-target crops and organisms with toxins (Reissig et al, 1986; Parris and Yokoi, 2003; El Sebae, 1993). It is estimated that only 1-75% of applied pesticides reach the target pests, depending on the type of pesticide, topography and soil composition, erosion, climate and evaporation, and leaching and run-off rates; the remaining 25-99% is lost to the environment (Parris and Yokoi, 2003). Ozone depletion can occur when organic solvents and aerosol propellants are retained in the stratosphere (El Sebae, 1993). Pesticides can continue to disrupt the environment after application by remaining in the environment for long periods – from a few weeks to several decades, accumulating in animals and plants, and indirectly exposing animals or people that consume organisms that have accumulated pesticides (Reissig et al, 1986; El Sebae, 1993).

The harmful effects associated with their use notwithstanding, pesticides are not proven to be essential for use in rice cultivation (EJF, 2002). According to the Environmental Justice Foundation (2002), higher use of pesticides does not necessarily equate to an increase in productivity. A rice productivity study by IRRI in the Philippines found that pesticide use is disadvantageous when including health costs in an economic analysis (Rola, 1993, cited by EJF, 2002). EJF cites a message from several agricultural organizations that insecticide use is unnecessary in most Cambodian rice fields because “the pest population is not high enough to seriously affect harvests” (Global Pesticide Campaigner, 1993, cited by EJF, 2002, p. 27). A study by IRRI was cited showing that “there is no net economic benefit of pesticide use in tropical rice cultivation” (TVE, 2001, cited by EFJ, 2002). EJF (2002, p. 27) concludes that “it is likely that a large proportion of insecticide used in Cambodian rice production is unnecessary,” and recommends that pesticides should only be used on rice as a last resort (EJF, 2002).

2.2.2.2. Integrated Pest Management

Integrated pest management offers an alternative for preventing yield loss from pests without relying on harmful chemical pesticides. The aims of IPM are to reduce pre-harvest yield losses from pests, reduce pesticide use, protect beneficial insects, minimize risks to humans and other organisms, and benefit rice ecosystems (Quijano-Guerta, 2015; Alam et al, 2016; FAO Code of Conduct, cited by EJF, 2002). The goals of IPM as defined by EPIC are to “optimize existing biotic and abiotic interactions in Cambodian rice fields to enhance pest regulation and minimize preharvest yield loss while protecting the health of rural communities and their environments” (Quijano-Guerta, 2015, p. 1). While no method of pest control can increase yield, IPM seeks to prevent the maximum “physiologically obtainable” yield from being “significantly reduced by pests” (Reissig et al, 1986, p.6). Pest eradication is not the end goal of IPM; rather the goal is to manage pests within “levels that are uneconomical to control” (Reissig et al, 1986, p.5). IPM discourages the development of pest populations through natural control mechanisms so as to not disrupt the rice agroecosystem (FAO Code of Conduct, EJF, 2002).

To reach these goals, IPM strategies integrate biological, genetic, chemical, cultural, and temporal pest control methods (EJF, 2002; Reissig et al, 1986; Quijano-Guerta, 2015; Norton, 2005). Proper application of pesticides may be allowable in the practice of IPM as a last resort if alternative controls fail to reduce pests (Reissig et al, 1986; Quijano-Guerta, 2015; Alam et al, 2016). Pesticides applied under IPM must be non-residual, environmentally-friendly, low-mammalian-toxic and applied only when necessary (Reissig et al, 1986; OIRED (d), 2013). Components of IPM processes include farmer knowledge of pest species and rice ecosystems, pest monitoring, cultural methods, resistant varieties, predictive modeling, and biological control tactics (Norton, 2005; Alam et al, 2016; Quijano-Guerta 2015). Certain practices may decrease pests but also decrease yield or increase another pest; thus, each farmer must decide which practices to use to yield the best results (Reissig et al, 1986). Managing crops well and accurately and timely diagnosing problems through this multi-faceted approach can prevent losses from rice pests in “an environmentally sound and sustainable manner” (IRRI (b), no date; EJF, 2002, p.31). Alam et al (2016) found that the implementation of robust IPM strategies can ameliorate ecological crises caused by the excessive use of pesticides.

The key components comprising the rice IPM package for Cambodia, designed by EPIC, will include the following practices: 1) Host-plant resistance against planthoppers, bacterial leaf blight, and rice blast; 2) Biological control agents and botanical insecticides; 3) Seedbed management for golden apple snail damage suppression; 4) Trap barrier system and community action and bait containing the native parasitic protozoan *Sarcocystis singaporensis* for rodent control; 5) Integration of agronomic/cultural, mechanical, and chemical methods for weed management in rice; and 6) Planting date management as an escape strategy for rice viruses (Quijano-Guerta, 2015).

Jahn (1997) recommends resistant varieties as the best method for controlling rice diseases in Cambodia. Resistant varieties are improved varieties of rice seed that resist pests. A variety is resistant if it “produces a larger amount of a good quality crop than other varieties grown under the same conditions and exposed to similar populations of insects and diseases” (Reissig et al, 1986, p.343). Reissig et al (1986) declare that the use of resistant varieties limits pests without increasing costs for farmers. Resistant varieties are important for managing stem borers, to which traditional varieties are more susceptible, and tungro (Jahn, 1997). In 2008, about 40% of Cambodian rice acreage was under improved varieties (CARDI, cited by USDA FAS, 2010).

The combination of natural enemies of pests and biological pesticides or controls can fight pests (OIRED (a), no date). Insecticides may “kill parasitoids and result in Gall midge outbreaks in the long run;” Gall midge can be controlled by avoiding pesticides, and combining resistant varieties with biological control agents that exist within the rice field (Jahn, 1997, p.85). Botanical insecticides or bio-pesticides such as Trichoderma, which is used to help control the soil-borne fungal disease rice blast, can be used (OIRED (a), no date; Quijano-Guerta, 2015). Biological control refers to natural checks that keep pest populations under control, for example beneficial insects (Reissig et al, 1986). One way to achieve biological control of natural pest populations is the “no spray for 40 days” method (Quijano-Guerta, 2015).

It is not necessary to apply pesticides within the first 40 days of planting rice; if damage is done to the rice, for example by the leaf-folder, during the early stages of growth, it is possible for the plant to fully recover without any loss (IRRI (c), no date; EJF, 2002). Pesticides applied during this period are not necessary to prevent rice damage, but instead they can cause damage to beneficial insect populations, which can lead to pest outbreaks (IRRI (c), no date; EJF, 2002).

Waiting 40 days before spraying insecticides allows beneficial insects to flourish, which may prevent pests from causing damage after the initial time period.

Manual weeding by hand, with the use of tools such as hoes and sickles, can control damage from weeds (IRRI (d), no date). Mechanical instruments, such as rotaries or push weeders, may also be used IRRI (d), no date). These forms of cultural control are safer for the environment than chemical herbicides, they are cost-effective, and they are simple to implement (IRRI (d), no date). Downsides to weeding by hand are that it is time-consuming and labor intensive (IRRI (d), no date). Transplanting rice instead of direct seeding is more conducive for manual weeding, whereby a seedbed is created to manage rice and pests (Islam, n.d.).

Women in Asia are typically the ones who manage household finances, obtain credit farm and household credit, make marketing decisions, and are knowledgeable about pest identification (Miller, 2005). Women often drive decisions about pest management strategies through their influence over finances and budgeting (Hamilton, 2005). Hamilton (2005) remarked that women are just as likely as men to prioritize pesticide expenditures, but Miller (2005, p.36) cited that Asian women were interested in “practices that might reduce expenditures on pesticides” (though they themselves are not the ones who typically apply the pesticides). Hamilton (2005, p.263) observed women to be “more involved than expected” regarding decision-making on pesticide use. The typical gender roles in Asian farming households can be summarized by specifying that “control-intensive” are usually handled by women, while men handle “power-intensive” operations (Miller, 2005, p.36).

Hamilton (2005) writes that women largely lack information on IPM and the ability to obtain such information or technical support for IPM practices (Hamilton, 2005). Pest management programs that disregard women’s participation may further marginalize women and worsen their livelihoods (OIRED (b), 2013). It is important to involve both men and women in IPM, and gain an accurate view of women's roles in pest management (Miller, 2005). Hamilton (2005, p.265) suggests that "the adoption of IPM can help women to improve their positions in both households and markets."

To meet the "White Gold" policy target of one million tons of exported rice, exports need to almost double from the 2015 measurement (Open Development Initiative, 2015). Pest management must be improved to consistently prevent yield losses and achieve a stable level of production (Matsukawa, 2016). In addition to an increase in production, rice quality must be enhanced to achieve the goal of expanding exports. Cambodian rice is known for its high-quality varieties, such as the fragrant variety Phka Rumduol, which was considered the best rice variety in the world for three years (Quijano-Guerta, 2015). However, high levels of pesticide residue on rice product are not accepted by countries with strong food safety controls (EJF, 2002). Pesticide levels must be reduced in order to improve quality, meet international standards, and expand exports to include such countries (EJF, 2002; Quijano-Guerta, 2015). EJF (2002) cites that the use of IPM in Asia has been shown to reduce pesticide usage by 50-100% without impacting yield. Adoption of IPM in Cambodia can reduce pesticide use to improve rice quality for exports.

Certain IPM practices have been shown to result in higher yields compared with not using IPM, minimize negative environmental impacts, and relieve farmers of financial burden (Alam et al, 2016). Alam et al (2016, p.9; p.1-2) claim, "IPM techniques are extremely efficient and environmentally friendly and are the foundation of sustainable cropping systems," and "The widescale adoption of IPM in rice agroecosystem could provide a tremendous net benefit to farmers in a number of countries." Quijano-Guerta (2015, p.1) states, "Because of its importance for the Cambodian people, the rice sector is a strategic development target in the country. An increase in rice sector productivity is expected to have positive effects on the livelihood of Cambodian rural communities."

The benefits of IPM are apparent; nevertheless, Asian farmers have been slow to adopt IPM practices due to the difficulty of implementation and lack of understanding of the corresponding economic benefits (Reissig et al, 1986; Alam et al, 2016; Norton, 2005). A pilot program of farmer field schools (FFS), which began in 1992 by Canada's International Development Research Centre (IDRC) and was continued by FAO in 1995, began laying groundwork for distributing IPM throughout Cambodia (Nesbitt, 1997). One year later, the Cambodia National IPM Programme began with the mission of promoting of IPM practices to farmers (Chhay, 2017). Chhay recounts that since 1996, around 4,000 IPM–based farmer field schools have been executed for rice in Cambodia with positive results (NIPMP, 2015, cited by Chhay, 2017). However, Cambodia lacks a rice IPM package conducive for the specialized growing conditions in the country, has limited capacity to spread IPM, and lacks education to promote IPM (Quijano-Guerta, 2015). Because of this gaping need, EPIC aims to devise and distribute an IPM package throughout Cambodia that will "help to increase the Cambodian rice sector's agricultural productivity, improve rural income, close the gender-knowledge gap in rice pest management, and reduce the negative health and environmental effects associated with current levels of pesticide use" (Quijano-Guerta, 2015, p.3).

3. Chapter 3: Methods, Data, and Models

3.1. Conceptual Framework

3.1.1. Conceptual Framework

Adoption theories and economic models attempt to explain the decisions by individual farmers and their families to use IPM technology. In this chapter, technology, innovation, and adoption will be defined. Adoption and diffusion will be explained by the diffusion of innovation theory. Economic theory will be used to explain adoption before providing examples of the determinants of adoption and empirical models for IPM adoption.

A technology is a design used to achieve a desired outcome. Technology reduces uncertainty by supplying information about the "cause-effect relationships on which the technology is based" (Rogers, 1995, p.13). Rogers (1995, p.11) defines an innovation as "an idea, practice, or object that is perceived as new by an individual." The innovation may be an original idea or it may seem new to the individual because it is a novel persuasion or the first time the decision is embraced by that particular individual (Rogers, 1995).

Though technological innovations typically offer some benefits, these advantages are not always clear to the prospective adopters. The potential adopters tend to have some uncertainty about the expected consequences of the innovation, though technology itself reduces uncertainty through the provision of information (Rogers, 1995). Therefore, an agricultural technological innovation is a factor that changes the production function and for which farmers have some uncertainty that diminishes over time as they acquire experience and information on the technology (Feder and Umali, 1993).

Diffusion is the process by which an innovation is communicated, through planning or spontaneously, among members of the population over time (Feder and Umali, 1993; Rogers, 1995). Diffusion involves the exchange of information regarding a new idea; the act of diffusing these new ideas leads to social change (Rogers, 1995). Some uncertainty exists due to the newness of the idea, but the innovation reduces uncertainty through the transfer of information (Rogers, 1995). Individuals, or agricultural households, must decide whether to reject or adopt the new technology, and if adopted, at what intensity to use it (Feder and Umali, 1993). Afterwards, the entire population is examined to identify trends in adoption over time (Feder and Umali, 1993). Thus, adoption is a process that can be measured by the incidence of adoption, intensity of adoption, and the rate of adoption. The diffusion of innovation theory is used to explain the process and rate of adoption of technology.

Rogers (1995) lays out the diffusion of innovation theory in terms of an innovation-decision process, which leads to either adoption - a decision to use of the innovation, or to rejection - a decision not to use the innovation. The individual does not necessarily continue with his or her initial decision; at any point the decision can be reversed, whereby the individual discontinues use of the innovation or later adopts it after initial rejection (Rogers, 1995). In the innovation-decision process, the decision-making unit passes through five steps: (1) knowledge, when the individual first learns about the innovation, (2) persuasion, when the individual forms an attitude toward the innovation, (3) decision, when the individual decides to adopt or reject the technology, (4) implementation, when the individual makes use of the new idea, and (5) confirmation, when the individual confirms his or her decision by either continuing to use the adopted innovation or rejecting it (Rogers, 1995).

Adopters can be grouped into five categories: innovators, early adopters, early majority, late majority, and laggards. The rate of adoption measures the speed by which the innovation is adopted throughout the population. The distribution of the rate of adoption is an S-shaped curve, with low initial levels of adoption, a majority of adoption occurring in the middle stages, and slow adoption towards the end of the cycle (Rogers, 1995).

Adoption decisions can be represented by the choice model in consumer theory. This assumes that farmers make decisions by choosing the technology, traditional or new, and its intensity of use that maximizes their expected utility. Farmers maximize utility from the consumption of income (including the produced commodity, leisure, and a residual cash endowment), subject to a production constraint (a function of household labor supply and demand for hired labor, cash inputs, the amount of land allocated to the new and traditional technology, and other exogenous variables), a time endowment constraint, a cash endowment constraint, and a market balance constraint (Feder and Umali, 1993). Farmers maximize their expected utility given their level of risk aversion, the stochastic interrelationship between the technologies, and the effects of other socioeconomic factors such as age, education, and wealth (Feder and Umali, 1993). This constrained optimization yields the technology adoption equations along with the family and off-farm labor supply and hired labor demand equations (Feder and Umali, 1993).

3.1.2. Theoretical Framework

Fernandez-Cornejo (1996) describes a choice model for the adoption of IPM technology, where i represents the grower and j represents adoption. The utility of a farmer's adoption is represented by U_{ij} for the ith grower and the jth level of adoption (j = 1 for adoption, 0 for non-adoption). Grower i is likely to adopt IPM if the utility of adopting, U_{i1}, is larger than the utility of not adopting, U_{i0}. The utility level is in practice unobservable, but IPM adoption, I_i (I_i=1 for adopters, 0 for non-adopters) is observed.

The utilities are treated as random variables, to form the equation:

$$U_{ij} = V_{ij} + e_{ij}, \tag{1}$$

Where V_{ij} represents the profitability of adopting or not adopting for the ith grower, and e_{ij} accounts for errors and unobserved attributes for each grower and adoption level. The probability that the ith grower will adopt IPM is:

$$P_{i1} = P(I_i = 1) = P(U_{i1} > U_{i0}). \tag{2}$$

This equation is then transformed to the following equation for the probability of adoption:

$$P(I = 1) = F(\gamma Z), \tag{3}$$

Where $F(\cdot)$ is the cumulative normal distribution, and the vector Z corresponds to the explanatory variables for adoption.

Key explanatory variables influencing the household's adoption decision for agricultural technologies include farm size, risk and uncertainty, human capital, labor availability, credit, land tenure, and supply constraints. The effect of farm size on adoption depends on characteristics of the technology; smaller farms are less likely and slower to adopt technologies with high fixed costs, which may be due to credit constraints (Feder, Just, and Zilberman, 1985). Rather than having a distinctive effect, farm size tends to be a proxy for other factors such as access to credit, risk-bearing capability, access to scarce inputs and information, wealth, and more (Feder, Just, and Zilberman, 1985). Risks can include subjective and objective measures, such as yield uncertainty and susceptibility to pests, but are rarely found in empirical studies due to the difficult nature of study (Feder, Just, and Zilberman, 1985). Human capital corresponds to farmers' "ability to perceive, interpret, and respond to new events," and can be related to formal schooling (Schultz 1981, p. 25, cited by Feder, Just, and Zilberman, 1985, p.275).

The availability of labor affects adoption; farmers subjected to labor shortages may be deterred from adopting labor-intensive technologies, while households with more labor tend to adopt those same technologies (Feder, Just, and Zilberman, 1985). In a similar way, the availability of credit affects adoption; farmers without accumulated savings or access to capital markets may not adopt modern agricultural technologies as quickly (Feder, Just, and Zilberman, 1985). Based on empirical studies, land tenure has an ambiguous effect on adoption; for example, Parthasarathy and Prasad (1978, cited by Feder, Just, and Zilberman, 1985) found mixed evidence for adoption by tenants as opposed to land owners depending on the type of technology in question. Finally, constraints on complementary inputs such as seeds and fertilizers can prevent farmers from adopting (Feder, Just, and Zilberman, 1985).

3.2. Data Sources and Methodology

3.2.1. Household Survey

Data for this study were collected through a household survey of rice farmers in four provinces of Cambodia. The data collected from this survey will act as a baseline for the EPIC program to develop and distribute an IPM rice package and examine impacts of adoption on field productivity and profitability (Quijano-Guerta, 2015). The survey was conducted in collaboration with the Centre d'Etude et de Developpement Agricole Cambodgien (CEDAC), the General Directorate of Agriculture (GDA), and IRRI. Harvey Reissig, former director of the Pesticide Management and Education Program at Cornell University, collaborated on the pesticide portion of the questionnaire.

The purpose of the survey was to collect data on the following topics: household and farm characteristics, organization or group membership of farmers, agricultural knowledge sources, rice production, rice pests, pest management practices, IPM training, gender information related to pest management, and pesticide use, safety, and knowledge. A mixture of closed- and open-ended questions was asked. The survey had twelve sections. Section 1 described the location and time of the survey. Section 2 obtained consent and the coordinates of the household location. Section 3 obtained demographic information. Section 4 gathered information about household assets. Section 5 gathered information about land currently being farmed. Section 6 asked about organization and group membership. Section 7 asked about agricultural knowledge sources. Section 8 asked respondents to share information about rice production, consumption, and sales in general and over the last twelve months. Section 9 gathered information about rice pests and pest management, including IPM, over the last year. Section 10 asked respondents the number of times they have received IPM training, if any, and from whom they have received it. Section 11 asked questions about gender and pest management. Section 12 gathered more detailed information on pesticide use, effectiveness, safety, and knowledge. The household survey instrument can be found in Appendix B.

3.2.2. Sample Design

Four provinces are the focus of the EPIC program and this survey due to their concentration of rice farming and variation in type of land farmed. The chosen provinces are lowland rain-fed and dry-season irrigated production areas, the two ecosystems in which most of the rice in Cambodia is produced (Quijano-Guerta, 2015). Two provinces, Battambang and Kampong Thom, are located in the Tonle Sap region, which is a USAID Feed the Future focus region. The other two provinces, Takeo and Prey Veng, have the largest rice production in Cambodia and are recommended for study by Cambodian Agricultural Research and

Development Institute (CARDI) and GDA (Quijano-Guerta, 2015). Two districts from each province were selected by IRRI for the EPIC project. Those districts are Trang and Bati from Takeo, Peam Ro and Preah Dsach from Prey Veng, Santouk and Steung Sen from Kampong Thom, and Banan and Thma Koul from Battambang. Within each district, five villages were randomly chosen for the survey from a complete list of villages in each district. This list was obtained from a government website. Prior to arrival, the survey supervisor arranged a meeting with the village chief. Upon arrival to the village, a meeting was held with the chief or his wife, who produced a record of households in his or her village. From the records, ten rice-farming households were randomly selected for interview. In total, 400 farmers were interviewed from forty villages in the eight districts.

3.2.3. Data Collection

The surveys were conducted in the native language of Khmer by three enumerators from CEDAC and one supervisor who also acted as an enumerator. The four enumerators had previous experience conducting agricultural surveys. A graduate research assistant from Virginia Tech randomized the households, managed the team of enumerators in the field, and checked for quality assurance in the collection of data.

Planning and pilot testing of the survey took place from June 20-24, 2016 among the research advisor and graduate research assistant from Virginia Tech, collaborator from Cornell, project supervisor from CEDAC, collaborators from IRRI, collaborators from GDA, and enumerators. The districts and villages were determined, the questionnaire was revised based on input from CEDAC staff members and pilot testing, and training was given to the enumerators. The surveys were conducted from June 28-July 27, 2016. Each interview lasted approximately

15-60 minutes. Following the survey, the paper forms were scanned, converted to PDF files, and stored on Google Drive.

After collection, the data from the questionnaires were entered into an Excel spreadsheet by two interns and were cleaned by the graduate research assistant.

3.3. Variables

3.3.1. Variable Construction

In other empirical studies, researchers define adoption of IPM by classifying farmers into two or more groups, based on their participation in IPM practices. Haque, Kabir, and Nishi (2016) defined adoption of IPM by classifying farmers from the study area into three categories (low, medium, and high practices) after assigning each farmer a score based on the frequency of use of 20 IPM practices. Singh et al (2008) defined adoption of IPM by weighting IPM practices by complexity and then counting the number of practices used by each farmer. Harris (2011) divided farmers into two groups (IPM farmers and non-IPM farmers) based on the percentage of IPM practices adopted by each farmer. Kabir & Rainis (2015) divided farmers into two groups: adopters of IPM used at least one or more IPM practices, while non-adopters used pesticides only.

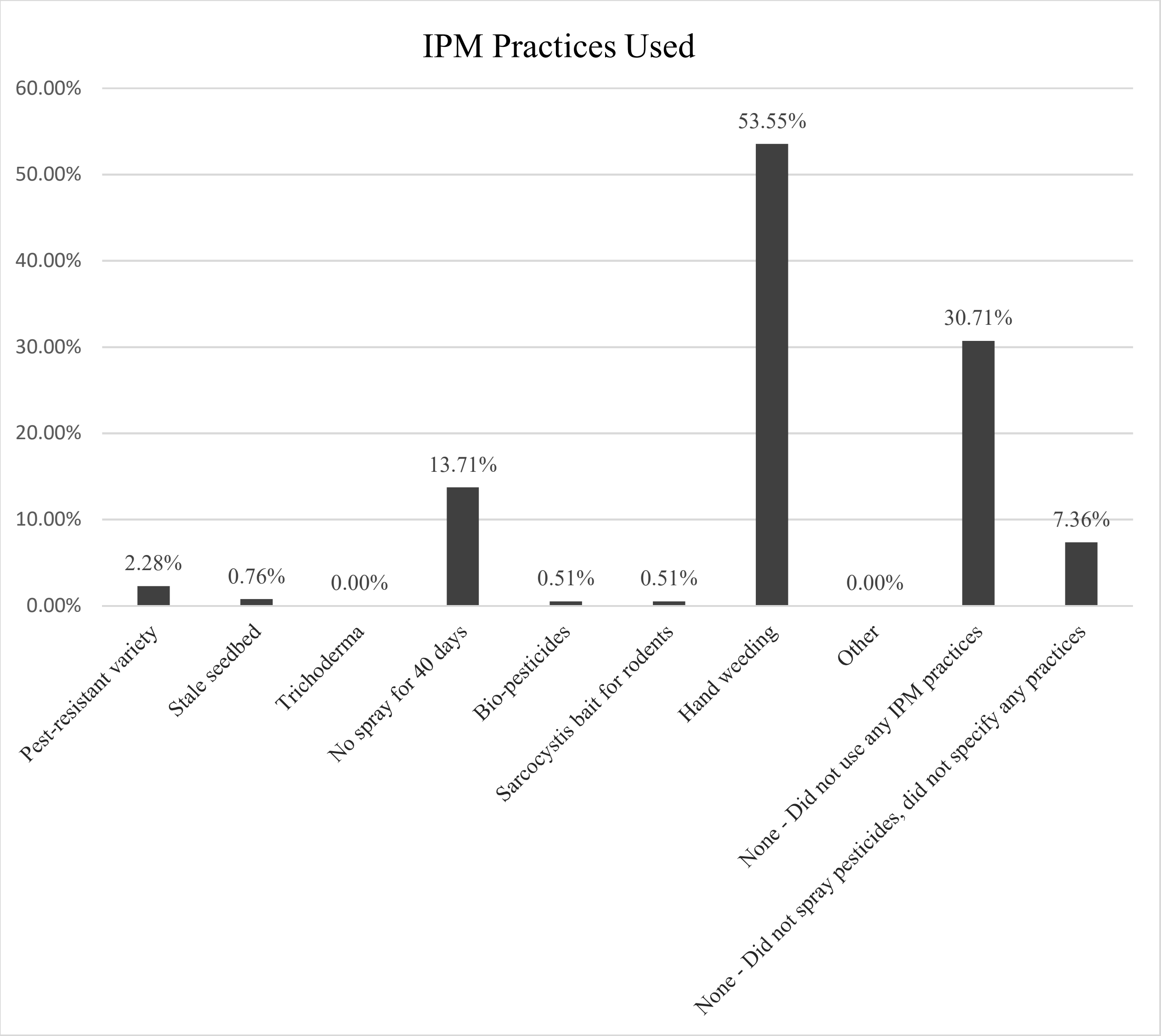
In the household survey, we asked farmers to respond if he/she used one of the following non-pesticide or minimal-pesticide practices to control rice insect, disease, weed, or rodent pests in the last twelve months: pest-resistant variety; stale seedbed (sequential harrowing or harrowing followed by a non-selective herbicide); apply Trichoderma on seeds or seedlings, no insecticide spray for the first 40 days; apply bio-pesticides such as neem, *Bt*, and metarhizium, and Beauvaria; *Sarcocystis* bait for rodents; hand weeding at recommended growth stage; and/or another practice specified by the farmer.

Table 3.1 and Figure 3.1 show the non-pesticide or minimal-pesticide IPM practices used in the past 12 months by the respondents in our survey to control rice insect, disease, weed, or rodent pests. 30.71% (126) of the respondents did not use any IPM practices, and did apply pesticides to their rice during the last 12 months. The most frequently used IPM practice was hand weeding, with 53.55% of the 394 farmers employing this technique. The second most frequently used practice was "no spray for 40 days," with 13.71% of farmers using the technique. The remaining IPM practices were used by few farmers.

Table 3.1 IPM Practices

IPM Practice	**Response**	**Obs.**
Pest-resistant variety	2.28% (9)	394
Stale seedbed	0.76% (3)	
Trichoderma	0.00% (0)	
No spray for 40 days	13.71% (54)	
Bio-pesticides	0.51% (2)	
***Sarcocystis* bait for rodents**	0.51% (2)	
Hand weeding	53.55% (211)	
Other not listed	0.00% (0)	
None		
Did not spray pesticides, but did not respond "yes" to using any of the above practices	7.36% (29)	
Did not use any IPM practices	30.71% (126)	
Total who responded "none"	38.07% (155)	

Figure 3.1 IPM Practices Used



Based on these summary statistics and the examples in the literature, a variable was created that grouped farmers into three adoption levels: high adopters, low adopters, and non-adopters. A farmer was placed in the high adopter group if he/she used two or more IPM practices to control rice pests in the last twelve months. A farmer was placed in the low adopter group if he/she used only one IPM practice to control rice pests in the last twelve months. A farmer was placed in the non-adopter group if he/she did not use any IPM practice to control rice pests in the last twelve months.

Table 3.2 shows the number of IPM practices used by farmers in the study area. 10.15% of farmers used two rice IPM practices in the last twelve months; none used more than two practices. 50.51% of farmers used only one IPM rice practice in the last twelve months. Additionally, there is a group of 29 farmers (7.36% of the sample population) who did not apply any pesticides to their rice during the last twelve months, but who, when asked by the enumerator, did not respond positively to using any of the IPM practices listed above (these farmers are listed as "Did not use pesticides or specify any practice" in Table 3.2). Since these farmers did not spray any pesticides, they are considered adopters of the IPM practice "no spray for 40 days," but as they did not use more than one practice, they are placed in the low adopter group.[4] In total, 57.87% of farmers are placed in the low adopter group. 31.98% of farmers used zero rice IPM practices in the last twelve months.

Table 3.2 Number of IPM Practices Used

Number of IPM Practices Used	Response	Obs.
2 practices	**10.15% (40)**	394
Hand weeding + other	2.79% (11)	
No spray for 40 days + other, but not hand weeding	0.25% (1)	
Hand weeding + no spray for 40 days, but not other	7.11% (28)	
1 practice	**57.87% (228)**	
Hand weeding alone	43.65% (172)	
No spray for 40 days alone	6.35% (25)	
Other alone	0.51% (2)	
Did not use pesticides or specify any practice	7.36% (29)	
None	**31.98% (126)**	
No practices used	31.98% (126)	

In the survey, the gender of the respondent was recorded, and the respondent was asked whether the primary farmer was him/herself or his/her spouse. A variable was constructed to

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[4] We also ran the model excluding this group of 29 farmers. The results were very similar, so we decided to keep the observations. The results for the model excluding this group can be found in Appendix D.1.

record the gender of the primary farmer by identifying the gender of the respondent and whether the respondent or the respondent’s spouse was the primary farmer.

A variable was constructed which specifies the level of education of the primary farmer. First, the years of schooling of the primary farmer was recorded based on whether the primary farmer was the respondent or the respondent’s spouse. If the respondent’s spouse was the primary farmer, then the years of schooling of the spouse were recorded as the years of schooling for the primary farmer. Then, the primary farmers were grouped into three levels based on their number of years of schooling: if the farmer completed zero years of schooling, they are placed in a group of “no education,” if the farmer attended 1-6 years of schooling, they are placed in a group of “primary school,” and if the farmer attended 7 or more years of schooling, they are placed in a group of “secondary school.”

A variable was constructed to calculate the number of hectares of rice planted by each farmer. This variable was constructed by adding the number of hectares of rice planted in the last wet season (including the early season, May-July, and the regular season, June/July-December) and the number of hectares of rice planted in the dry season during the past twelve months.

A dummy variable was constructed which counts the number of respondents who hired labor to apply pesticides.

A variable was constructed for insect pest severity that groups the “none” and “low” responses into one group.

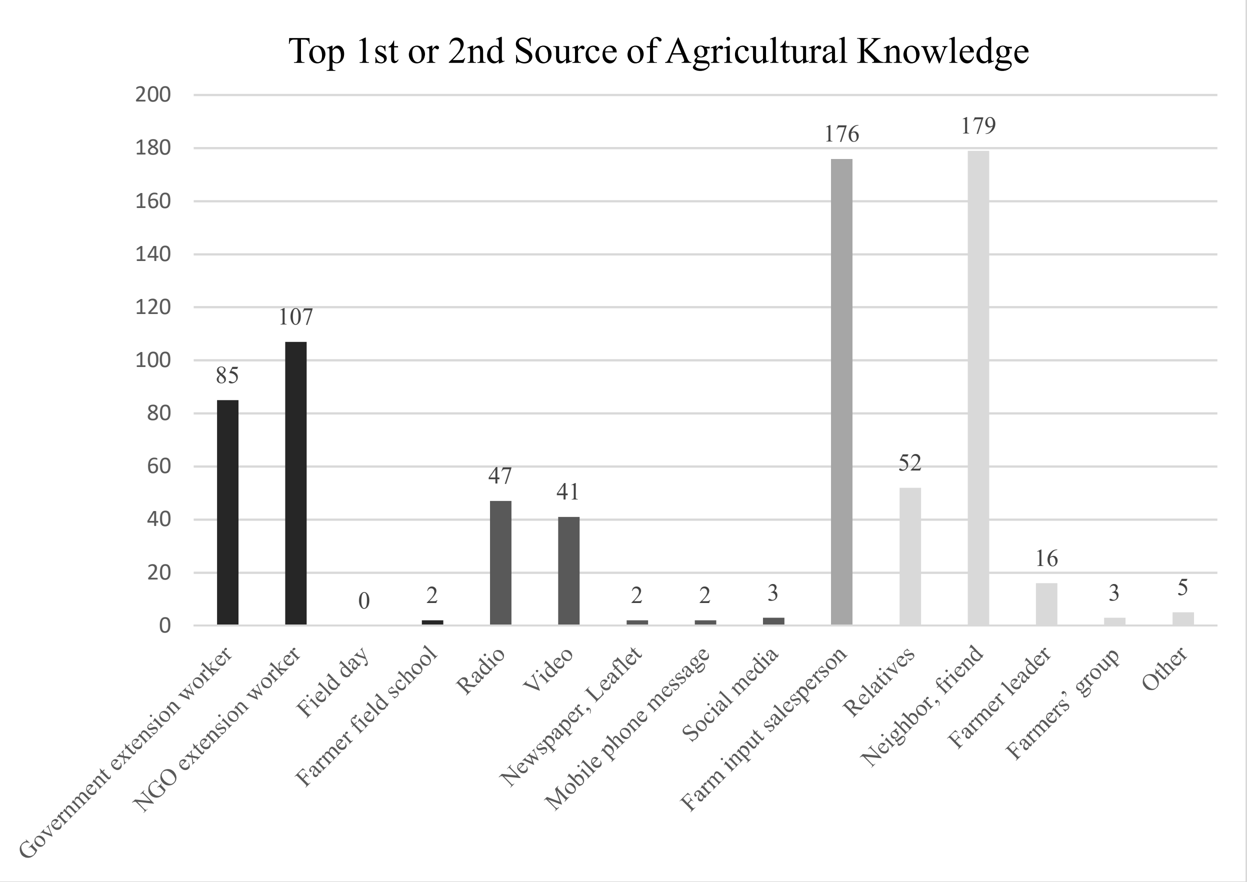
A variable was constructed for disease pest severity that groups the “none” and “low” responses into one group.

A dummy variable was constructed to represent the top two most important sources of agricultural information or advice received by farmers. Table 3.2 and Figure 3.2 show each agricultural knowledge source and the number of farmers who said that source was their primary or secondary source of agricultural knowledge. 384 farmers had a top source of knowledge, and 336 farmers had a secondary top source for a total of 720 responses.

Table 3.3 Primary and Secondary Sources of Agricultural Knowledge

Grouping	Source	Top 1st or 2nd Source	Total	Resp.
Extension	Government agricultural extension worker/center	85	194	720
	NGO agricultural extension worker	107		
	Field day	0		
	Farmer field school	2		
Media	Radio	47	95	720
	Video (TV, YouTube)	41		
	Newspaper, Leaflet	2		
	Mobile phone message	2		
	Social media (Facebook, etc.)	3		
Input Suppliers	Farm input salesperson	176	176	720
Personal source	Relatives	52	250	720
	Neighbor, friend	179		
	Farmer leader	16		
	Farmers' group	3		

Figure 3.2 Primary and Secondary Sources of Agricultural Knowledge



For each information source, farmers were placed into two groups depending on whether or not their primary or secondary source of agricultural information or advice came from extension, media, input suppliers, and personal sources, respectively. Extension sources included information received by farmers from government agricultural extension workers or centers, NGO agricultural extension workers, field days, or farmer field schools. Media sources included information received by farmers from radio, video such as television or YouTube, newspaper/leaflets, mobile phone messages, or social media such as Facebook. Input supplier sources included information received by farmers from farm input salespersons. Personal sources included information received by farmers from relatives, neighbors or friends, farmer leaders, or farmers' groups.

A variable was constructed to denote whether anyone in the household became ill from pesticide exposure. This variable was constructed based on the responses to the following question: “Have you or anyone in your family ever become ill from pesticide exposure?”

3.3.2. Summary Statistics

The Stata commands “tabulate” and “summarize,” with option “detail” are used to create summary statistics for key variables which will be discussed in sections 3.3.3. and 3.3.4. The following statistics are observed: adoption level, primary farmer’s gender, level of primary farmer’s education, top sources of agricultural information or advice, levels of severity of rice insect and disease pests, whether anyone in the household has ever become ill from exposure to pesticides, planting method, cropping pattern, number of times someone applied pesticides to rice during the last twelve months, years of experience in rice cultivation, number of members in the household who are able to work, distance from the farm to the nearest agricultural extension officer, hectares of land owned, hectares of rice planted in the last twelve months, and number of times the farmer has received training related to IPM. Summary statistics are provided in Tables 3.4 and 3.5.

Table 3.4 Summary Statistics

Indicator	**Response**	**Obs.**
Adoption level	Non-adopter: 31.98% (126) Low adopter: 57.87% (228) High adopter: 10.15% (40)	394
Gender of primary farmer	Male: 53.30% (210) Female: 46.70% (184)	394
Education level	No education: 17.01% (67) Some primary school (1-6 years): 47.21% (186) Some secondary school (7+ years): 35.79% (141)	394
Extension is a top source of agricultural knowledge	Extension is not a top source: 62.94% (248) Extension is a top source: 37.06% (146)	394
Media is a top source of agricultural knowledge	Media is not a top source: 79.95% (315) Media is a top source: 20.05% (79)	394

Input suppliers are a top source of agricultural knowledge	Input suppliers are not a top source: 55.33% (218) Input suppliers are a top source: 44.67% (176)	394
Personal sources are a top source of agricultural knowledge	Personal sources are not a top source: 42.13% (166) Personal sources are a top source: 57.87% (228)	394
Hired labor	Did not hire labor to apply pesticides: 80.96% (319) Hired labor to apply pesticides: 19.04% (75)	394
Insect pest severity	None: 64.21% (253) Medium: 24.62% (97) High: 11.17% (44)	394
Disease pest severity	None: 77.41% (305) Medium: 16.24% (64) High: 6.35% (25)	394
Illness from pesticide exposure	No one in household has become ill: 41.37% (163) Someone in household has become ill: 58.63% (231)	394
Planting method	Transplanted only: 11.17% (44) Utilized direct seeding: 88.83% (350)	394
Cropping pattern	Rice-fallow or Rice-Other: 74.11% (292) Rice-Rice: 20.05% (79) Rice-Vegetables: 5.84% (23)	394

Table 3.5 Additional Summary Statistics

Indicator	**Average**	**Min.**	**Max.**	**Median**	**Std. Dev.**	**Obs.**
Pesticide applications	2.22	0	15	2.00	2.27	394
Pesticide applications if > 0	2.92	1	15	2.00	2.18	299
Experience cultivating rice (years)	31.22	1	70	32.00	13.01	394
Household labor	3.58	1	10	3.00	1.52	394
Distance to ag. extension officer (km)	7.17	0.50	25.00	6.00	5.21	394
Land owned (ha)	2.13	0.00	23.00	1.30	2.90	394
Land owned (ha), if > 0	2.16	0.02	23.00	1.36	2.91	388
Hectares of rice planted	2.81	0.02	53.00	1.55	4.74	394
Number of times received IPM training	0.65	0	12	0.00	1.65	394
Number of times received IPM training, if > 0	2.88	1	12	2.00	2.38	89

Figures 3.3, 3.4, and 3.5 show the distribution of land owned, hectares of rice planted in the past 12 months, and distance from nearest agricultural extension worker, respectively.

Figure 3.3 Land Owned

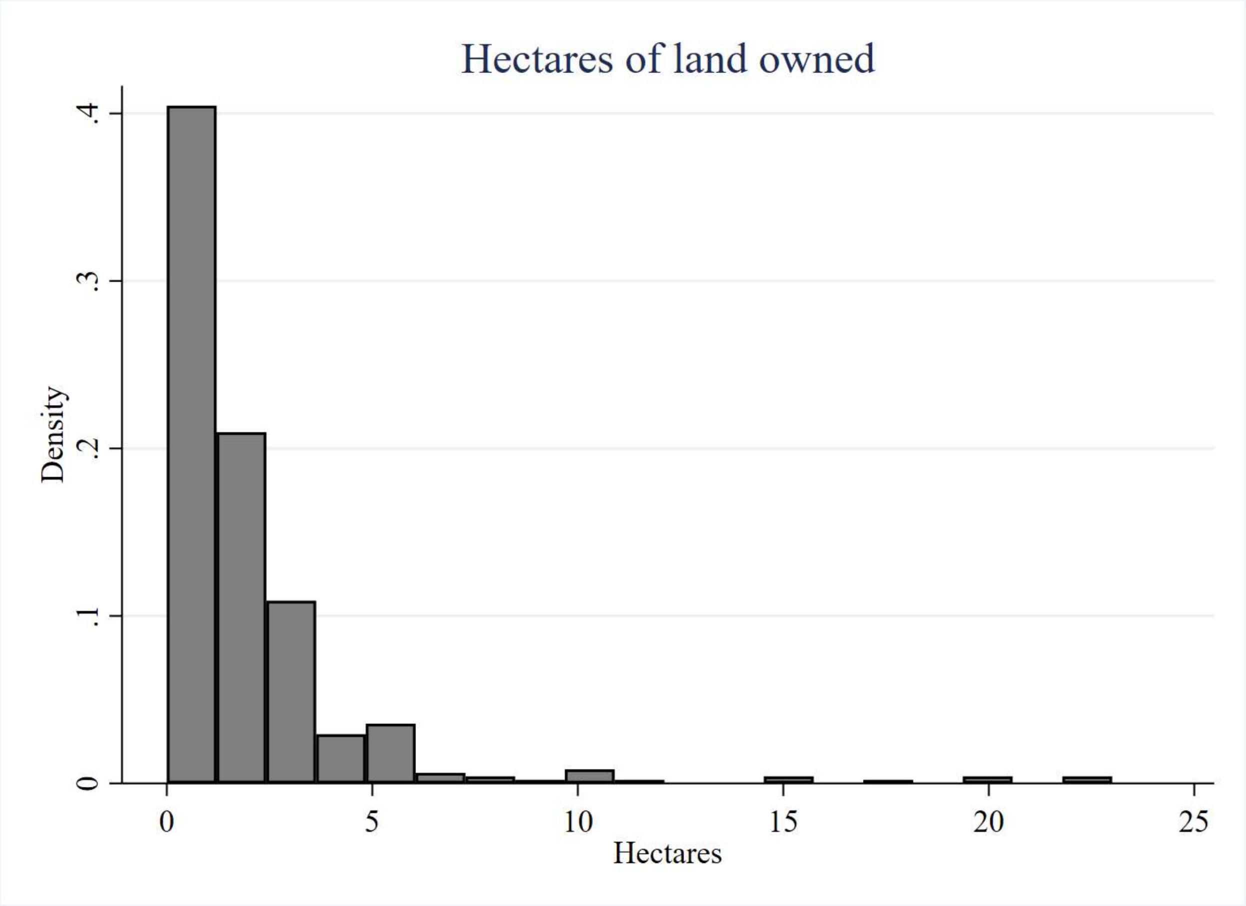


Figure 3.4 Hectares of Rice Planted

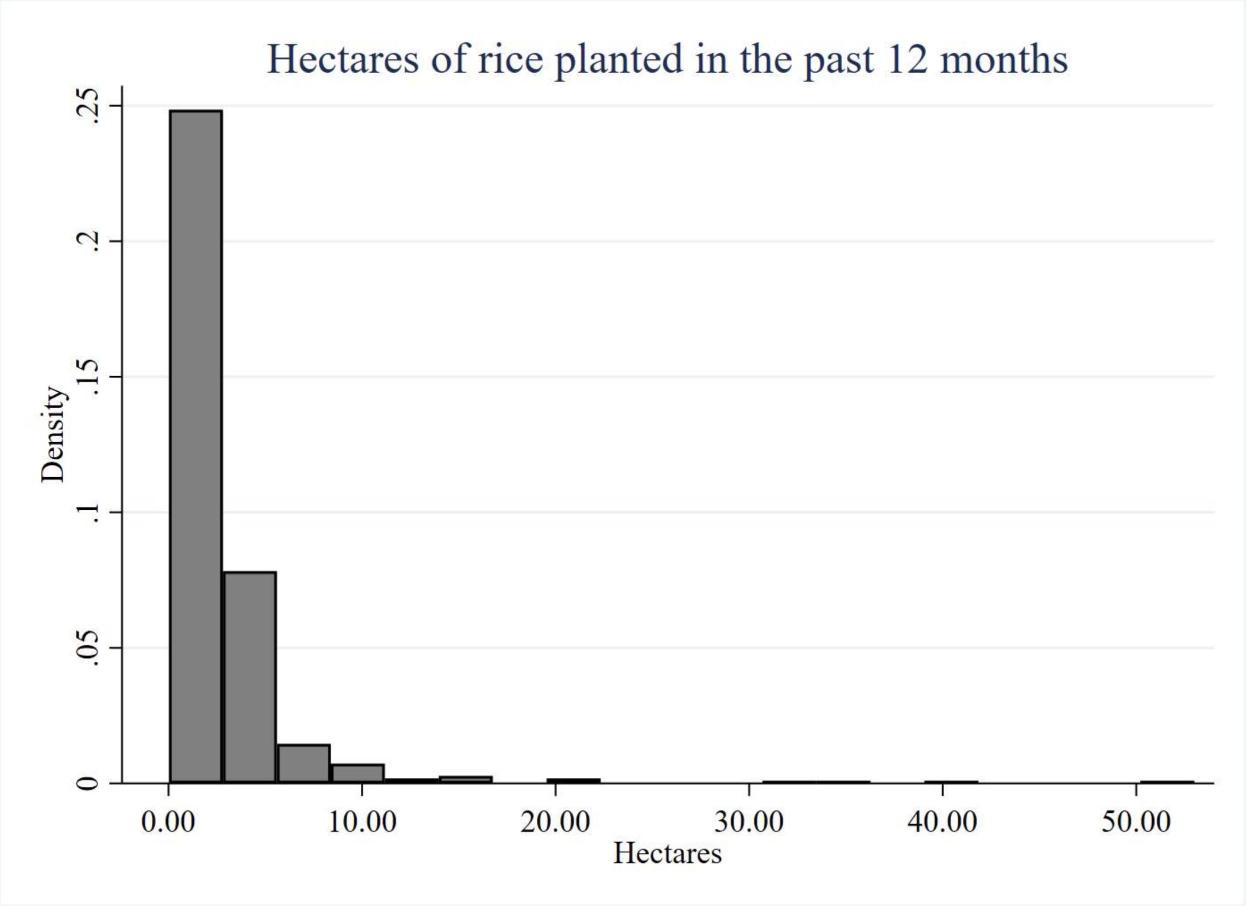


Figure 3.5 Distances from Nearest Agricultural Extension Worker

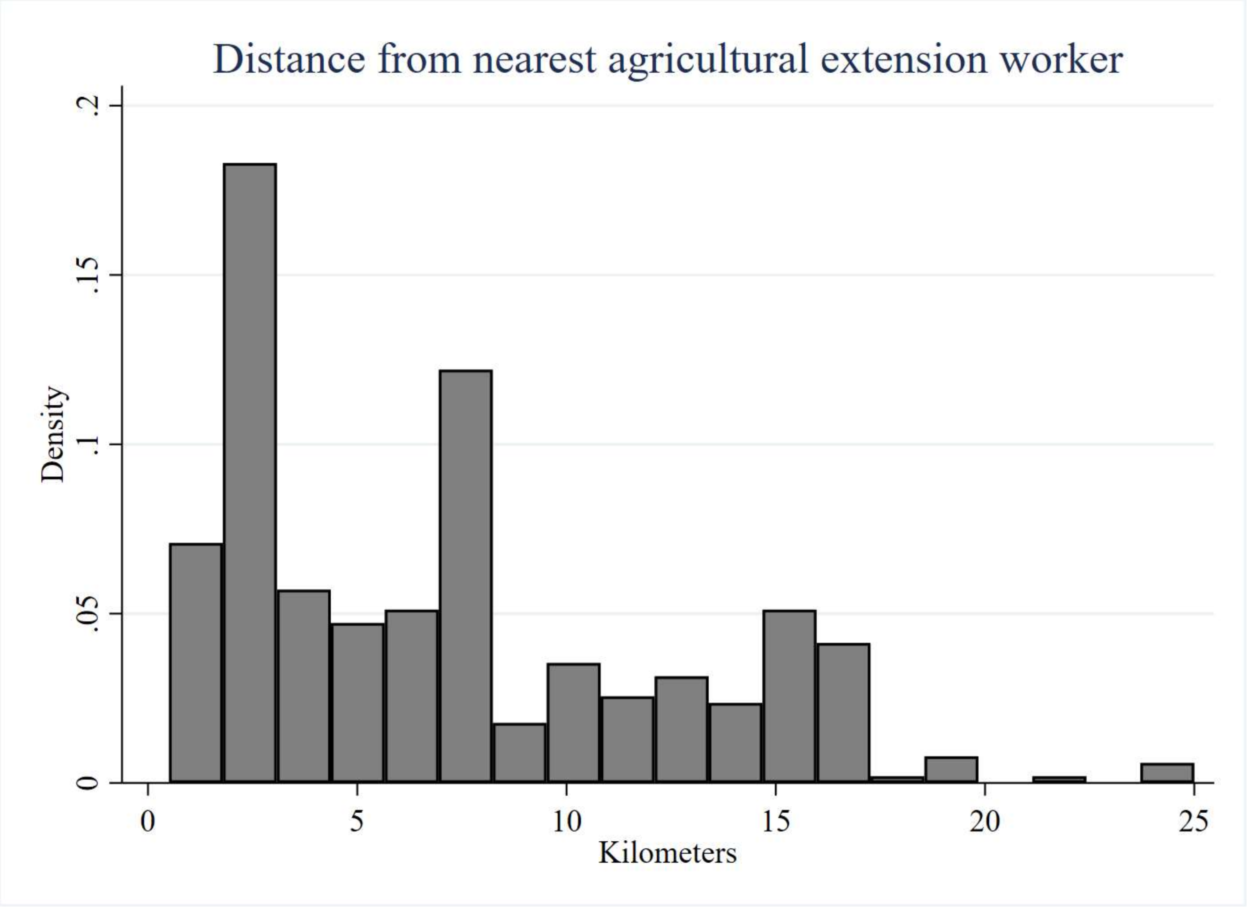


Table 3.6 summarizes gendered decision-making in pest management for the farmers in our sample. This table shows the influences of women on pest management decisions.

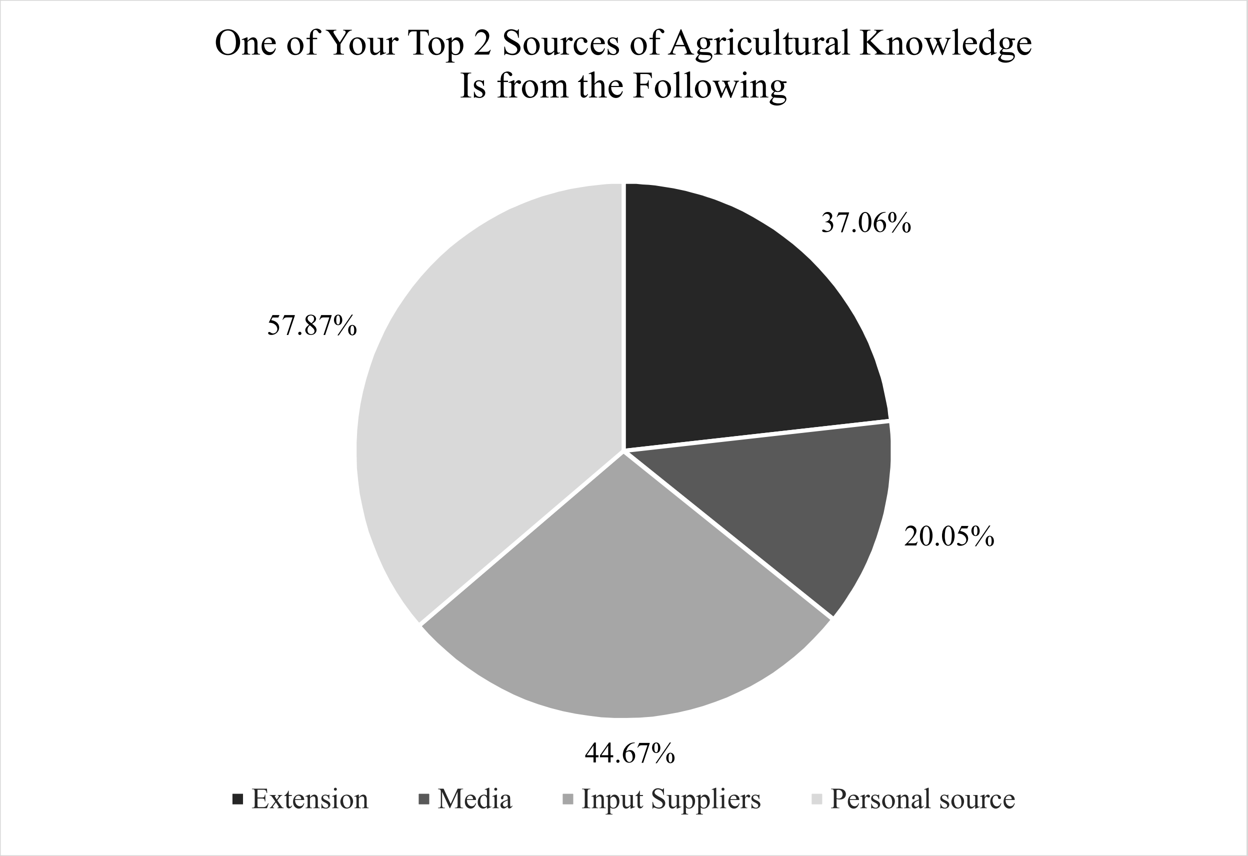
Table 3.6 Gender in Pest Management

Indicator	Husband or Male Head	Wife or Female Head	Both Spouses Equally	Other	No One	Obs
Who buys pesticides or other pest management products	39.95% (157)	25.45% (100)	4.33% (17)	7.07% (16)	26.21% (103)	393
Person who decides how much to spend on pesticides or pest management products	37.56% (148)	19.29% (76)	14.97% (59)	2.54 (10)	25.63% (101)	394
Person who mixes pesticides before they are applied to rice	34.01% (134)	26.14% (103)	1.02% (4)	10.41% (41)	28.43% (112)	394

Person who generally applies pesticides or pest management products	37.06% (146)	25.89% (102)	3.05% (12)	6.60% (26)	27.41% (108)	394
Person who decides what to do when pest problems occur	30.46% (120)	18.53% (73)	20.30% (80)	2.54% (10)	28.17% (111)	394
Person who decides how to spend money earned from selling rice	21.57% (85)	12.18% (48)	33.25% (131)	0.25% (1)	32.74% (129)	394
Who in your family normally attends any training that is given on IPM?	70.33% (64)	21.98% (20)	0.00% (0)	1.10% (1)	6.59% (6)	91

Figure 3.6 shows the proportion, out of 394 farmers in our sample, of farmers who claimed extension, media, input suppliers, and personal sources as one of their top two sources of agricultural knowledge. The percentages add up to more than 100% because 336 farmers identified both a primary and secondary agricultural knowledge source.

Figure 3.6 Top Sources of Agricultural Knowledge



3.3.3. Variables for Adoption Model

As mentioned in Section 3.1.1, adoption models are based on decisions farmers make given their income, production, and expected utility of the new farm technology. An equation modeling adoption of agricultural technology can include a variety of factors, including household labor supply, amount of farmland, and socioeconomic factors. Haque, Kabir, and Nishi (2016) modeled adoption of rice IPM practices in Bangladesh and included the following explanatory variables in their equation: age, education, family size, farm size, training exposure, experience of IPM practices, annual family income, extension media contact, organizational participation, innovativeness, and knowledge on IPM. Singh et al (2008) studied the adoption of IPM for rice paddy and cotton in India and included the following explanatory variables in their model: age, education, knowledge regarding negative externalities of pesticide use, perception of expected yield losses, group membership, farm size, gross value of crop, frequency of meeting with extension personnel, IPM training, and years of experience in practicing IPM. Abdollahzadeh, Damalas, and Sharifzadeh (2017) examined adoption of biological control methods for rice in Iran and included the following explanatory variables in their model: age, education, family members, farm family laborers, experience in rice cultivation, area under rice cultivation, rice yield, annual farm income, off-farm income, the use of resistant rice varieties, source of information, compatibility, perceived self-efficacy, facilitating conditions, perceived usefulness, perceived ease of use, perceived cons of pesticides, perceived pros of pesticides, safe pesticide use, and trust in dealers of agricultural inputs.

Based on intuition and models in the literature, the following explanatory variables will be used in the adoption model in this study: gender of primary farmer, experience in rice cultivation education, available labor from the household, distance from nearest agricultural extension office or agent, wealth (as measured by total hectares of land owned), total hectares of rice planted in the last 12 months, number of times received IPM training, and top sources of agricultural information. The rationale for including each variable, and its expected sign and significance, are detailed below. The expected signs are summarized in Table 3.7. Descriptions of each variable are provided below in Table 3.9[5].

(1) Female primary farmer - Females are expected to be more likely to adopt IPM techniques because women may be more protective of their family's health and thus more likely to use an alternative to pesticides. Ricker-Gilbert et al. (2008) found that male farmers were significantly less likely to adopt complex IPM practices in Bangladesh.

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[5] Correlation values between variables for adoption model can be found in Appendix D.2.

(2) Experience – Farmers with more experience in rice cultivation are expected to be more likely to adopt. Experience is included rather than age because other studies found experience to be more important than age in influencing adoption of IPM. Haque, Kabir, and Nishi (2016) explain that greater experience in rice farming gives farmers the ability to compare various rice cultivation techniques, and allows them to understand the economic and environmental costs associated with pesticides, both of which influence the farmers to adopt IPM practices. Kabir and Rainis (2015) and Abdollahzadeh, Damalas, and Sharifzadeh (2017) found rice farming experience to be positively associated with adoption, but not significant.

(3) Education – Farmers with higher levels of education are expected to be more likely to adopt compared to farmers with no education. Higher levels of education can enable farmers to better understand differences in pest management strategies; deeper understanding of pest management practices may make a farmer more likely to adopt IPM. Abdollahzadeh, Damalas, and Sharifzadeh (2017) found education level to have a positive and significant effect on adoption of biological control for Iranian rice farmers. Kabir and Ruslan (2013), Ricker-Gilbert et al. (2008), and Amir et al. (2012) obtained a similar finding.

(4) Household labor - Households with more family members who are able to work are expected to be more likely to adopt because IPM practices are more labor-intensive. Kabir & Rainis (2015) reason that labor-intensive technology is more readily adopted by families that are able to offer more farm labor. Ricker-Gilbert et al. (2008) found that labor constraint (measured by farm area divided by number of family members) had a significant and negative effect on adopting simple IPM practices.

(5) Distance - Greater distance to the nearest agricultural extension officer is expected to have a negative effect on adoption. Interaction with extension personnel gives farmers more information and increases their knowledge of agricultural practices, which motivates the

farmers to use IPM (Haque, Kabir, and Nishi, 2016; Kabir and Rainis, 2015). Extension officers may have less contact with farmers who are farther away and hence be less likely to adopt. Ricker-Gilbert et al. (2008) found that extension agent visits significant influence adoption of complex IPM technologies.

(6) Wealth – Land owned[6] is included as a proxy for wealth. Higher wealth, as is signified by a greater amount of land owned, is expected to increase the likelihood of adoption. Abdollahzadeh, Damalas, and Sharifzadeh (2017) found annual farm income to be a positive and significant factor influencing adoption of biological controls. Kabir and Rainis (2015) found that ownership of land was associated with a higher probability of adoption; however, they also found that annual income was not a significant determinant of adoption.

(7) Hectares of rice planted – Hectares of rice planted is expected to influence adoption, but the expected sign is ambiguous. Kabir and Ruslan (2013) and Kaibr and Rainis (2015) found that larger farms were more likely to adopt IPM practices., the reason for this being that farmers who cultivate a large area of land are more convinced of the benefits of using IPM. However, Abdollahzadeh, Damalas, and Sharifzadeh (2017) and Singh et al. (2008) found that larger farms were less likely to adopt because labor-intensive IPM practices are more difficult to carry out over a larger area of land.

(8) Training times - Farmers who have received a greater number of IPM trainings are expected to be more likely to adopt IPM practices. Rice farmers who attend training programs can gain information and learn skills in practicing IPM techniques which positively influence the adoption of such practices (Haque, Kabir, and Nishi, 2016; Kabir and Rainis, 2015). Amir et

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[6] A wealth variable was constructed but it was not as meaningful as using a proxy variable, because we had limited information on household income from the questionnaire.

al. (2012), Singh et al. (2008), and Haque, Kabir, and Nishi (2016) found that attending IPM trainings had a positive and significant effect on adoption of rice IPM practices.

(9) Interaction between female and training times – The interaction between female and training times analyzes the effect of the number of times female primary farmers received IPM training. This interaction shows if females who receive more training are more likely to adopt, as compared with males who have received training and men and women who have not received training. Based on intuition regarding the variables female and training times, females who have received a greater number of IPM trainings are expected to be more likely to adopt IPM practices.

(10) Top sources of agricultural information – Media, extension contact, and other interactions can encourage positive perceptions of IPM amongst farmers (Kabir and Rainis, 2015, p. 1425). Kabir and Rainis (2015, p. 1425) recognize that "information seeking behaviors have a positive role in technology adoption decision." Abdollahzadeh, Damalas, and Sharifzadeh (2017) found that farmers who received information from agricultural extension workers had better technical knowledge about IPM practices, which positively influences farmers' perceptions of the use of the technology. Top sources of agricultural information from extension and media are expected to have a positive effect on adoption. Information from farm input suppliers are expected to have a negative effect. The expected sign on information from personal sources is ambiguous. Kabir and Rainis (2015) found that contact with extension personnel and attending farmer field school both had positive and significant influences on adoption. Haque, Kabir, and Nishi (2016) found that extension media contact had a significant and positive effect on adoption. Mauceri (2004) found that receiving information from extension sources (farmer field school and field days), media sources

(pamphlets), and personal sources (exposure to other farmers) significantly influenced farmers' adoption of IPM.

Table 3.7 Expected signs on independent variables in adoption model

Name	Variable	Expected sign
FEMALE	Female primary farmer	+
EXP	Experience in rice cultivation	+
EDUCPRIM	Primary school	+
EDUCSEC	Secondary school	+
HSHLDLABOR	Available household labor	+
DISTANCE	Distance from agricultural extension officer	-
LANDOWNED	Land owned (proxy for wealth)	+
HECTARESRICE	Hectares of rice planted	~
TRAININGTIMES	Number of times received training	+
FEMALE* TRAININGTIMES	Interaction variable between FEMALE and TRAININGTIMES	+
EXTENSION	Extension is a top source of agricultural information	+
MEDIA	Media is a top source of agricultural information	+
INPUTSUPPLIERS	Input suppliers are a top source of agricultural information	-
PERSONALSOURCE	Personal sources are a top source of agricultural information	~

3.3.4. Variables for Pesticide Applications Model

The rationale for including each variable, and its expected sign and significance, are detailed below. The expected signs are summarized in Table 3.8. Descriptions of each variable are provided below in Tables 3.9 and 3.10.

(1) Adoption – Low and high levels of IPM adoption are expected to decrease the number of pesticide applications as farmers use alternatives to pesticides to manage their pests.

(2) Female primary farmer – Having a female primary farmer is expected to decrease the number of pesticide applications because women may be more protective of their family's health and use fewer pesticides or alternatives to pesticides.

(3) Experience – Greater experience in rice cultivation is expected to decrease pesticide applications. Farmers with more experience may better understand the effectiveness of applying the appropriate level of pesticides and the consequences of over-applying, which would lead them to apply the proper amount of pesticides.

(4) Education – Primary farmers who have any level of education (primary school or secondary school) are expected to be apply a fewer number of pesticides as compared with farmers who have no schooling. Farmers who are educated may have greater knowledge of the dangers of pesticides and may be able to read warning labels, which would lead them to apply the proper amount of pesticides rather than over apply pesticides.

(5) Wealth– Land owned is included as a proxy for wealth. Higher wealth, as is signified by a greater amount of land owned, is expected to increase the number of pesticide applications. Farmers who have more money can afford to buy more pesticides, which may encourage them to apply more than farmers who cannot afford as many pesticides.

(6) Hectares of rice – A greater amount of rice planted is expected to increase pesticide applications, though the association is not expected to be strong. Farmers with more land may use a greater number of pesticide applications to cover their land; however, they may use the same number of applications as those with smaller farms, using more pesticides in each application.

(7) Agricultural knowledge sources – Top source of agricultural information from extension is expected to decrease the number of pesticide applications, top source of agricultural information from input suppliers is expected to increase the number of pesticide applications, and the expected signs on top source of agricultural information from personal sources and media are ambiguous. Farm input salespersons are likely to convince farmers to buy more pesticides so that they can make more money. Farmers who consider these sellers a top

source of information are likely to be influenced to apply more pesticides compared to farmers who do not consider farm input suppliers a top source of agricultural information. Extension workers teach farmers how to manage their crops and pests, and teach farmers to apply proper amounts of pesticides. Farmers who receive information from extension sources are less likely to apply as many pesticides as someone who receives their information from another source. Farmers whose top source of information is from media might be influenced to apply more pesticides compared with someone whose top source is not from media and rather from extension; on the other hand farmers whose top source of information is from media might be influenced to apply less pesticides compared with someone whose top source is not from media and rather from input suppliers. Farmers whose top source of information is from a personal source might apply more or less pesticides compared with someone whose top source is not from a personal source (ex. from extension or from input suppliers).

(8) Hired labor – Hired labor is expected to increase pesticide applications. Households who hired labor to control pests are expected to apply more pesticides than households who did not hire labor.

(9) Insect pest severity[7]– The expected sign on the effect of higher severity of pests is ambiguous. Higher severity of pests may increase the number of applications of pesticide as it indicates a greater requirement for pest management. On the other hand, higher pest severity does not necessitate that farmers use pesticides to manage their pests; when pests are more severe, farmers may rely on alternative pest management strategies other than pesticides. Thus, higher severity of pests may predict a decrease in the number of pesticide applications.

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[7] Disease pest severity was dropped from the model due to high correlation with insect pest severity. See Appendix D.3 for correlation values.

(10) Illness from pesticide exposure – The expected sign on the effect of the occurrence of illness in a household as a result of pesticide exposure is ambiguous. Households whose members fell ill from pesticide exposure may apply fewer pesticides in order to prevent future illness. Mauceri (2004) found that potato farmers who had been ill from exposure to pesticides in the previous year turned to Integrated Pest Management to control pests. However, the occurrence of illness indicates previous use of pesticides.

(11) Method of planting rice – Direct seeding is expected to increase pesticide applications. Hand weeding is more difficult with direct seeding, in which farmers scatter seeds irregularly throughout the field, as compared with transplanting, in which rice plants are aligned in rows. Transplanting rice into seedbeds "confines the crop to a small area where weeds can be removed easily by hand and insects can be removed by hand or sweep nets" (Islam, n.d.). In addition, transplanting older seedlings prevents pest buildup because of reduced time in the field (Islam, n.d.). Thus, farmers who direct seed, rather than or in addition to transplanting rice, are expected to apply a higher number of pesticides to control weeds.

(12) Cropping pattern – Rice-fallow or rice-other and rice-vegetable cropping patterns are expected to decrease the number of pesticide applications. A rice-rice cropping pattern may be associated with higher pest severity, which is expected to be associated with higher pesticide usage, compared with rice-fallow or rice-other and rice-vegetable patterns. In tropical rice-growing areas, leaving the field fallow during the dry season is known to lower the incidence of pests as it prevents pest populations from building in size (Isalm, n.d). Breaking up the crop cycle of rice by leaving the field fallow is expected to decrease the number of pesticide applications as fewer pests are present. Rotating rice with a non-rice crop, such as vegetables, removes the source of food for rice pests and prohibits the pest population from increasing in size (Isalm, n.d). Thus, breaking up the crop cycle of rice with

vegetables is expected to decrease the number of pesticide applications as fewer pests are present.

Table 3.8 Expected signs on independent variables in pesticide applications model

Name	Variable	Expected sign
ADOPTLOW	Low adoption	-
ADOPTHIGH	High adoption	-
FEMALE	Female primary farmer	-
EXP	Experience	-
EDUCPRIM	Primary school	-
EDUCSEC	Secondary school	-
LANDOWNED	Land owned (proxy for wealth)	+
HECTARESRICE	Hectares of rice planted	+
EXTENSION	Extension is a top source of agricultural information	-
MEDIA	Media is a top source of agricultural information	~
INPUTSUPPLIERS	Input suppliers are a top source of agricultural information	+
PERSONALSOURCE	Personal sources are a top source of agricultural information	~
HIRELABOR	Hired labor	+
INSECTSMED	Insect pest severity is medium	~
INSECTSHIGH	Insect pest severity is high	~
ILLNESS	Illness from pesticide exposure	~
DIRECTSEED	Use of direct seeding to plant rice	+
CROPFALLOW	Cropping pattern of rice is rice-fallow or rice-other	-
CROPVEG	Cropping pattern of rice is rice-rice	-

3.4. Econometric Models

3.4.1. Adoption Model

Econometric analysis is conducted to estimate the effects of the previously mentioned predictor variables on the probability of the dependent variable outcome. In this study, the dependent variable ADOPT is limited to three outcomes – high adoption, low adoption, and non-adoption. In the case of a limited dependent variable, the linear probability regression model can be used, but with two main disadvantages: despite the model predicting probabilities (that always lie between zero and one), the fitted probabilities in the estimated model are allowed to be less than zero or greater than one; also, the partial effects of explanatory variables are constant even if the variable appears in level form (Wooldridge, 2013). Because of these drawbacks, logistic regression, which ensures that the predicted probabilities for the dependent variable lie between zero and one, is preferable (Wooldrige, 2013). Maximum Likelihood Estimation (MLE), rather than Ordinary Least Squares (OLS), is used when the logistic model is nonlinear (Wooldridge, 2013); in the case where the dependent variable is censored, OLS estimates are biased (Mudiwa, 2011). Under general circumstances, the MLE estimator is consistent, asymptotically normal, and asymptotically efficient (Wooldridge, 2013). MLE is based on the density of y given x; because of this, the heteroskedasticity of the variance in y given x is automatically accounted for (Wooldridge, 2013).

Unlike linear regression models, logistic regression does not require a linear relationship between the independent and dependent variables, it does not assume normal distribution of the independent variables or the error term, and homoscedasticity is not necessary (Statistics Solutions (a), 2017). Logistic regression requires a discrete dependent variable and assumes correct fit of the model, independence of error terms, linearity of independent variables and log odds, and large samples sizes of at least 10 cases per independent variable (Statistics Solutions (a), 2017).

In the logistic regression model, the linear probability model undergoes a logit or probit transformation (Capps and Kramer, cited by Harper et al, 1990). Their interpretation is similar, but the logit model assumes the log distribution while the probit model assumes normal distribution (Statistics Solutions (b), 2017).

Abdollahzadeh, Damalas, and Sharifzadeh (2017) used a multinomial logit model to estimate adoption of biological control for rice in Iran; Harper et al (1990) used a binary logit model to estimate adoption of an IPM practice for rice in Texas; Kabir and Rainis (2015) used a binary logit model to estimate adoption of IPM for vegetable farmers in Bangladesh; Mudiwa (2011) used a binary logit model to estimate adoption of conservation farming in Zimbabwe; and Kodamanchaly (2001) used a binary logit model to estimate adoption of IPM in Bangladesh. Based on these examples, and because the dependent variable takes on three values, a multinomial logit model is chosen is used to estimate adoption for this study.

3.4.1.1. General Logistic Regression Model

A general form of the binary logistic response model explains the effects of x_j on the response probability and can be written as:

$$Pr(\mathrm{y} = 1|\boldsymbol{x}) = G(\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k) = G(\beta_0 + \boldsymbol{x\beta}), \tag{4}$$

where $Pr(\mathrm{y} = 1|\mathbf{x})$ represents the response probability, where $\mathrm{y} = 1$ is a success,

$\boldsymbol{x}$ represents the full set of explanatory variables,

β_0 is the intercept,

$\beta_1 \ldots \beta_k$ are the coefficients of the explanatory variables,

$x_1 \ldots x_k$ are the explanatory variables, and

$\boldsymbol{x\beta}$ is a shortened form for $\beta_1 x_1 + \cdots + \beta_k x_k$

(Wooldrige, 2013). In the logit model, the logistic function G is chosen to ensure that the probabilities for the previous equation are strictly between zero and one for all values of parameters $\boldsymbol{\beta}$ and explanatory variables $\boldsymbol{x}$ (Wooldridge, 2013). The logistic function G, which is between zero and one for all real numbers z, appears below:

$$G(z) = \frac{\exp(z)}{[1 + \exp(z)]} = \Lambda(z) \tag{5}$$

(Wooldridge, 2013).

The response probability for logit models can be derived from an underlying latent variable model:

$$y^* = \beta_0 + \boldsymbol{x\beta} + e, \quad y = 1[y^* > 0], \tag{6}$$

where y^* is an unobserved latent variable (Wooldridge, 2013). The equation $y = 1[y^* > 0]$ takes on a value of 1 if the event in brackets is true, and is 0 otherwise (Wooldridge, 2013). It is assumed that e is independent of $\boldsymbol{x}$ and has the standard logistic distribution (Wooldridge, 2013).

Because of the nonlinear nature of $G(\cdot)$, the partial effect of a continuous variable x_j on the response probability must be calculated using calculus:

$$\frac{\delta p(\boldsymbol{x})}{\delta x_j} = g(\beta_0 + \boldsymbol{x\beta})\beta_j, where\ g(z) \equiv \frac{dG}{dz}(z) \tag{7}$$

(Wooldridge, 2013). The partial effect of a discrete variable can be calculated using the following equation:

$$G[\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k(c_k + 1)] - G(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k c) \tag{8}$$

(Wooldridge, 2013).

The multinomial logit model is an extension of the binary model (Eq. 4) in the case where the dependent variable has more than two outcomes (Wooldridge, 2002). The response probability for multinomial logit models is expanded from Eq. 4 to:

$$Pr(\mathrm{y} = \mathrm{j}|\boldsymbol{x}) = G(\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k) = G(\beta_0 + \boldsymbol{x\beta}), \tag{9}$$

where y is a random variable taking on the values $\{0, 1, \ldots, J\}$ (Wooldridge, 2002). In this extended model, $G(z)$ takes on the following form:

$$G(\boldsymbol{x}\beta_j) = \frac{\exp(\boldsymbol{x}\beta_j)}{\left[1 + \sum_{h=1}^{J} \exp(\boldsymbol{x}\beta_j)\right]}, \quad j = 1, \ldots, J \tag{10}$$

$\boldsymbol{x}$ is a $1xK$ vector of explanatory variables, and

β_j is a $Kx1$ vector of unknown parameters for $j = 1, \ldots, J$ (Wooldridge, 2002).

3.4.1.2. Specific Empirical Logistic Regression Model

The adoption model in this study is specified as

$$\begin{aligned} Pr(ADOPT = j|\boldsymbol{x}) \\ = {} & G[\beta_0 + \beta_1 FEMALE + \beta_2 EXP + \beta_3 EDUCPRIM \\ & + \beta_4 EDUCSEC + \beta_5 HSHLDLABOR + \beta_6 DISTANCE \\ & + \beta_7 LANDOWNED + \beta_8 HECTARESRICE \\ & + \beta_9 TRAININGTIMES + \beta_{10} FEMALE \\ & * TRAININGTIMES + \beta_{11} EXTENSION + \beta_{12} MEDIA \\ & + \beta_{13} INPUTSUPPLIERS + \beta_{14} PERSONALSOURCE \\ & + \varepsilon] \end{aligned} \tag{11}$$

where

$ADOPT$ is the dependent variable taking on the values $\{j = 0, 1, 2\}$ for non-adoption, low adoption, and high adoption, respectively,

$G(\cdot)$ is represented by Eq. 10,

β_0 is the intercept,

$\beta_1 \ldots\ \beta_{14}$ are the regression coefficients of each explanatory variable,

the explanatory variables are FEMALE, EXP, EDUCPRIM, EDUCSEC, HSHLDLABOR, DISTANCE, LANDOWNED, HECTARESRICE, TRAININGTIMES, FEMALE*TRAININGTIMES, EXTENSION, MEDIA, INPUTSUPPLIERS, and PERSONALSOURCE, and

ε is the error term. The variables are described in Table 3.9. The multinomial logistic regression is run in Stata using the command *mlogit y* x_i.

Table 3.9 Variable descriptions

Name	**Variable**	**Description**	**Type**
ADOPT	Adoption level	Level of adoption of IPM practices (Non-adopter = no practices used Low adopters = 1 practice used High adopters = 2 practices used)	Discrete
FEMALE	Female primary farmer	Primary farmer with respect to rice production is female (Base: Primary farmer is male)	Discrete
EXP	Experience	Years of experience in rice cultivation	Continuous
EDUCPRIM	Primary school	Primary farmer attended 1-6 years of school (Base: No education)	Discrete
EDUCSEC	Secondary school	Primary farmer attended 7+ years of school (Base: No education)	Discrete

HSHLDLABOR	Available household labor	Number of members in the household who are able to work	Continuous
DISTANCE	Distance	Distance from farm to nearest agricultural extension officer in kilometers	Continuous
LANDOWNED	Land owned	Total hectares of land owned by the household	Continuous
HECTARESRICE	Hectares of rice planted	Total hectares of rice planted in the wet and dry seasons during the last 12 months	Continuous
TRAININGTIMES	Number of times received training	Number of times the farmer has received training related to IPM	Continuous
FEMALE* TRAININGTIMES	Interaction variable between FEMALE and TRAININGTIMES	Number of times female primary farmers have received training related to IPM (Base: Male farmers and/or female farmers who did not receive IPM training)	Discrete
EXTENSION	Extension is a top source of agricultural information	One of the top two sources of agricultural information or advice is from extension (government agricultural extension worker or center, NGO agricultural extension worker, field day, or farmer field school) (Base: One of the top two sources is not from extension)	Discrete
MEDIA	Media is a top source of agricultural information	One of the top two sources of agricultural information or advice is from media (radio, video such as television or YouTube, newspaper/leaflet, mobile phone message, or social media such as Facebook) (Base: One of the top two sources is not from media)	Discrete
INPUTSUPPLIERS	Input suppliers are a top source of agricultural information	One of the top two sources of agricultural information or advice is input suppliers (farm input salesperson) (Base: One of the top two sources is not input suppliers)	Discrete
PERSONALSOURCE	Personal sources are a top source of agricultural information	One of the top two sources of agricultural information or advice is a personal source (relative, neighbor or friend, farmer leader, or farmers' group)	Discrete

		(Base: One of the top two sources is not from a personal source)	

3.4.2. Pesticide Applications Model

An explanatory variable is endogenous when it is jointly determined with the dependent variable in the model (Wooldridge, 2009). Endogeneity can occur when there are omitted variables that are correlated with omitted factors in the error term, when there is measurement error in the independent variables, or when there is reverse causality or selection bias (Lambert, (a), 2013). Endogeneity causes the OLS estimator to be biased (the estimator does not equal the true parameter β), and inconsistent (as sample size increases, the estimator does not tend to the true parameter β) (Wooldridge, 2009; Lambert (a), 2013).

Because the OLS estimator is biased and inconsistent when endogeneity is present, the Instrumental Variables (IV) estimator can be used instead (Wooldridge, 2013). IV estimators are essentially never unbiased, and can be particularly biased in small samples (Wooldridge, 2013). However, as sample sizes near infinity, IV estimators are consistent, which is an improvement over OLS (Wooldridge, 2013).

We can use the Instrumental Variables approach when we have a model,

$$y = \beta_0 + \beta_1 x + u, \tag{12}$$

where we think that one of the independent variables, x, is endogenous because it is correlated with the error term u, such that $\mathrm{Cov}(x,u) \neq 0$ (Wooldridge, 2013). To estimate the model, we need to find an instrumental variable, or instrument, z, for the endogenous variable x (Wooldridge, 2013). The following must be true of the instrument, observable variable z: 1) z must be uncorrelated with the error term u: $\mathrm{Cov}(z,u) = 0$, such that z has no partial effect on the dependent variable *y*; and 2) *z* must be correlated with endogenous explanatory variable *x*: Cov(*z*,*x*) ≠ 0 (Wooldridge, 2013). It is important to use a strong instrumental variable, because IV estimates can have large standard errors if *z* and *x* are weakly correlated (Wooldridge, 2013).

The following equation can be used to obtain the Instrumental Variables estimator of the parameter $\hat{\beta}_1$:

$$Cov(z, y) = \beta_1 Cov(z, x) + Cov(z, u). \tag{13}$$

With the assumptions $Cov(z, u) = 0$ and $Cov(z, x) \neq 0$, then

$$\beta_1 = \frac{Cov(z, y)}{Cov(z, x)}. \tag{14}$$

This equation can be solved by canceling the sample sizes in the numerator and denominator to obtain:

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{N}(z_i - \bar{z})(y_i - \bar{y})}{\sum_{i=1}^{N}(z_i - \bar{z})(x_i - \bar{x})}. \tag{15}$$

(Wooldridge, 2013).

3.4.2.1. General 2SLS IV Regression Model

In IV estimation of a multiple regression model, the primary model at hand is known as a structural equation. For example,

$$y_1 = \beta_0 + \beta_1 x_1 + \beta_2 w_1 + u. \tag{16}$$

In this equation, y_1 is correlated with u and thus is endogenous; x_1 is presumed to be correlated with u and thus is considered endogenous; and w_1 is uncorrelated with u and thus is exogenous (Wooldridge, 2013). A different exogenous variable z_1 serves as the instrumental variable for x_1;

z_1 is uncorrelated with u but does not appear in the structural equation (Wooldridge, 2013). A key assumption is that u has zero expected value: E(u)= 0 (Wooldridge, 2013). Because of the assumptions that the instrument z_1 affects the endogenous variable x_1 but is not correlated with the unobserved factors in the error term in y_1, the only way the z_1 instrument affects dependent variable y_1 in the 2SLS equation is through changes in the endogenous variable x_1 (Wooldridge, 2013; Lambert (b), 2013; Lambert (c), 2013).

The reduced form equation demonstrates the effect of z_1 on y_1 through changes in x_1 and can be written as:

$$x_1 = \delta_0 + \delta_1 w_1 + \delta_2 z_1 + v. \tag{17}$$

The reduced form equation shows an endogenous variable x_1 written in terms of exogenous variables w_1 and z_1 (Wooldridge, 2013). Additional exogenous explanatory variables can be added; if so, it should be assumed that there are no perfect linear relationships among the exogenous variables (Wooldridge, 2013). Homoskedasticity of u should be assumed (Wooldridge, 2013).

The IV estimator is a subset of the Two-Stage Least Squares estimator (2SLS) where there is one IV for each endogenous explanatory variable; 2SLS estimation is used when there are more instruments than endogenous variables (Wooldridge, 2013). The 2SLS estimator is obtained in two stages: the first stage of 2SLS is the regression of the reduced form equation, which gives estimates used to predict x_1 (Wooldridge, 2013). The second stage is the regression of the structural equation using the predicted value for x_1 obtained in the first stage (Wooldridge, 2013).

3.4.2.2. Test for Endogeneity

The structural equation for the pesticide model in this study is specified as:

$$\begin{aligned}
\text{PESTICIDEAPPS} \\
&= \beta_0 + \beta_1 ADOPT + \beta_2 FEMALE + \beta_3 EXP \\
&+ \beta_4 EDUCPRIM + \beta_5 EDUCSEC + \beta_6 LANDOWNED \\
&+ \beta_7 HECTARESRICE + \beta_8 EXTENSION + \beta_9 MEDIA \\
&+ \beta_{10} INPUTSUPPLIERS + \beta_{11} PERSONALSOURCE \\
&+ \beta_{12} HIRELABOR + \beta_{13} INSECTSMED \\
&+ \beta_{14} INSECTSHIGH + \beta_{15} ILLNESS \\
&+ \beta_{16} DIRECTSEED + \beta_{17} CROPFALLOW \\
&+ \beta_{18} CROPVEG + u
\end{aligned} \tag{18}$$

where

$PESTICIDEAPPS$ is the dependent variable,

β_0 is the intercept,

$ADOPT$ is a discrete variable that is suspected to be endogenous in the structural equation (see Table 3.8),

FEMALE, EXP, EDUCPRIM, EDUCSEC, LANDOWNED, HECTARESRICE, EXTENSION, MEDIA, INPUTSUPPLIERS, PERSONALSOURCE, HIRELABOR, INSECTSMED, INSECTSHIGH, ILLNESS, DIRECTSEED, CROPFALLOW, and CROPVEG are exogenous explanatory variables,

$\beta_1 \ldots\ \beta_{18}$ are the regression coefficients of each explanatory variable, and

u is the error term. The variables are described in Tables 3.9 and 3.10.

Table 3.10 Additional Variable Descriptions

Name	Variable	Description	Type
PESTICIDEAPPS	Pesticide applications	Number of times pesticides were applied to rice during the last 12 months	Continuous
ADOPTLOW	Low adoption	Level of IPM adoption is low (Base: non-adoption of IPM)	Discrete
ADOPTHIGH	High adoption	Level of IPM adoption is high (Base: non-adoption of IPM)	Discrete
HIRELABOR	Hired Labor	Household hired labor to apply pesticides Base: Did not hire labor	Discrete
INSECTSMED	Medium insect severity	Level of severity of rice insect pests is medium (Base: level of severity is low-none)	Discrete
INSECTSHIGH	High insect severity	Level of severity of rice disease pests is high (Base: level of severity is low-none)	Discrete
ILLNESS	Illness from pesticide exposure	Whether anyone in the household has ever become ill from exposure to pesticides (Base: No one has ever become ill)	Discrete
DIRECTSEED	Direct seeding	Method of planting rice includes direct seeding (Base: Method of planting rice is transplanting only)	Discrete
CROPFALLOW	Rice-fallow or Rice-other cropping pattern	Cropping pattern of rice is rice-fallow or rice-other (Base: Cropping pattern is rice-rice)	Discrete
CROPVEG	Rice-vegetable cropping pattern	Cropping pattern of rice is rice-vegetables (Base: Cropping pattern is rice-rice)	Discrete

There is reason to believe that the level of IPM adoption is correlated with omitted factors in the error term for the number of pesticide applications because the number of pesticide applications is jointly determined with the level of IPM adoption. Thus, the explanatory variable ADOPT was tested for endogeneity in relation to the dependent variable PESTICIDEAPPS.

The reduced form equation for the suspected endogenous variable ADOPT is specified as:

$$\begin{aligned} \text{ADOPT} = {} & \delta_0 + \delta_1 FEMALE + \delta_2 EXP + \delta_3 EDUCPRIM \\ & + \delta_4 EDUCSEC + \delta_5 HSHLDLABOR \\ & + \delta_6 DISTANCE + \delta_7 LANDOWNED \\ & + \delta_8 HECTARESRICE + \delta_9 TRAININGTIMES \\ & + \delta_{10} EXTENSION + \delta_{11} MEDIA \\ & + \delta_{12} INPUTSUPPLIERS \\ & + \delta_{13} PERSONALSOURCE + \delta_{14} HIRELABOR \\ & + \delta_{15} INSECTSMED + \delta_{16} INSECTSHIGH \\ & + \delta_{17} ILLNESS + \delta_{18} DIRECTSEED \\ & + \delta_{19} CROPFALLOW + \delta_{20} CROPVEG + v \end{aligned} \tag{19}$$

where

$ADOPT$ is the dependent variable,

δ_0 is the intercept,

FEMALE, EXP, EDUCPRIM, EDUCSEC, LANDOWNED, HECTARESRICE, EXTENSION, MEDIA, INPUTSUPPLIERS, PERSONALSOURCE are exogenous variables for ADOPT,

HSHLDLABOR, DISTANCE, and TRAININGTIMES are instruments for ADOPT,

HIRELABOR, INSECTSMED, INSECTSHIGH, ILLNESS, DIRECTSEED, CROPFALLOW, and CROPVEG are exogenous variables for PESTICIDEAPPS,

$\delta_1 \ldots\ \delta_{20}$ are the regression coefficients of each instrument, and

v is the error term. The variables are described in Tables 3.7 and 3.8.

To test whether ADOPTB is correlated with omitted factors in the error term (u) of the structural equation, we estimate the structural equation using OLS and 2SLS, directly compare the estimates, and determine if the differences are statistically significant (Wooldridge, 2013). If the 2SLS and OLS estimates differ significantly, then we will conclude that ADOPTB is correlated with u, ADOPTB must be endogenous, and we should use 2SLS to estimate the structural equation (Wooldridge, 2013). On the other hand, if ADOPTB is uncorrelated with u, we should estimate the structural equation by OLS (Wooldridge, 2013).

Assuming the instruments for ADOPTB and the exogenous variables for PESTICIDEAPPS are uncorrelated with u, ADOPTB is uncorrelated with u if and only if v is uncorrelated with u (Wooldridge, 2013). Thus, for equation

$$u = \delta_1 v + \varepsilon \tag{20}$$

where ε is uncorrelated with v and has zero mean, we test $H_0\colon \delta_1 = 0$ using a t-statistic (Wooldridge, 2013). This test is conducted by including v as an additional regressor in the structural equation, and conducting a t-test on the coefficient on v (Wooldridge, 2013). Because v is unobserved, we estimate the reduced form and obtain the reduced form residuals $\hat{v}$ (Wooldridge, 2013). If we can reject H_0 at a small significance level, we can conclude that ADOPTB is endogenous because v and u are correlated (Wooldridge, 2013).

The test is conducted as follows: first, the reduced form equation is estimated using MLE. The reduced form residuals, $\hat{v}$, are obtained. Then, the structural equation is estimated using OLS. The hypothesis $H_0\colon \delta_1 = 0$ is tested using a t-statistic. This test was conducted in Stata using the following commands: 1) *mlogit* x_1 w_i z_i 2) *predict v2_hat, p*, 3) *regress* y_1 x_1 w_i , and

4) *test v2_hat*. The significance level of the t-test was 0.195. We fail to reject the null hypothesis that $H_0: \delta_1 = 0$, and we cannot conclude that ADOPTB is endogenous. Thus, we choose to run the regression for the structural equation using the efficient OLS estimator. The regression is run in Stata using the command *regress* $y_1\ x_1\ w_i$.

4. Chapter 4: Results and Discussion

4.1. Objective I: Baseline Information

4.1.1 Extent of Adoption

High adopters include farmers who used two IPM practices to control rice pests in the last twelve months, low adopters include farmers who used one IPM practice to control rice pests in the last twelve months, and non-adopters include farmers who did not use any IPM practice to control rice pests in the last twelve months. Out of 400 farmers surveyed, six observations were dropped due to missing values or incoherent responses. Figure 4.1 shows that 40 (10.15%) of the 394 were found to be high adopters of IPM, 228 (57.87%) were found to be low adopters, and 126 (31.98%) were found to be non-adopters of IPM.

Figure 4.1 Extent of Adoption

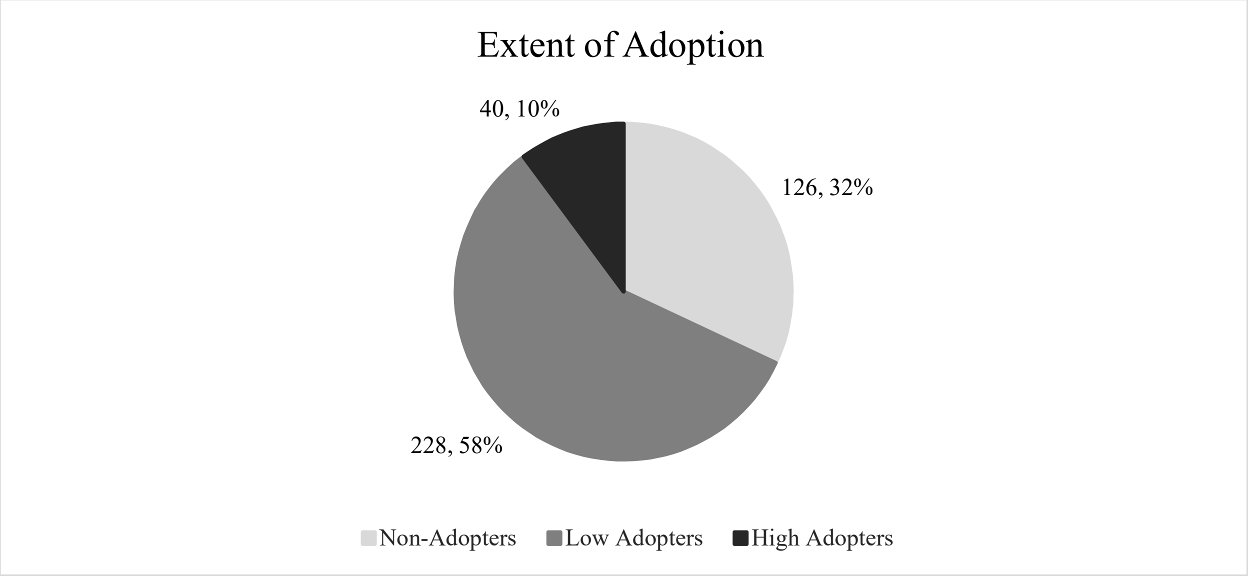
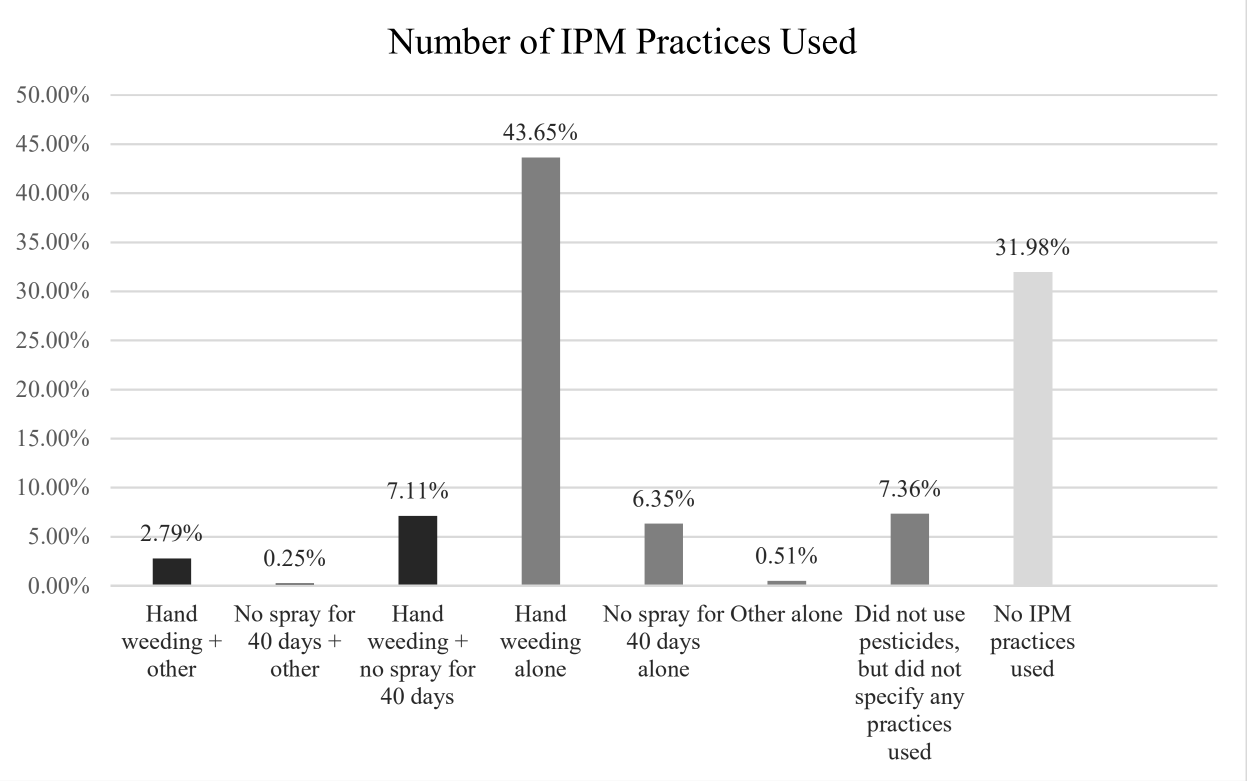


Figure 4.2 shows the number and type of IPM practices adopted. In the high adoption group, 2.79% of farmers (11) adopted hand weeding plus another IPM practice, 0.25% of farmers (1) adopted no spray for 40 days plus another IPM practice, 7.11% of farmers (28) adopted hand weeding plus no spray for 40 days. In the low adoption group, 43.65% of farmers (172) adopted hand weeding by itself, 6.35% of farmers (25) adopted no spray for 40 days by itself, 0.51% of farmers (2) adopted another IPM practice alone, and 7.36% of farmers (29) adopted no spray for 40 days because they did not use any pesticides at all. In the non-adoption group, 31.98% of farmers (126) adopted no IPM practices.

Figure 4.2 Number of IPM Practices Used



4.1.2 Farm Household Characteristics by Adoption Group

The Stata commands "tab *varname*, summarize (*varname2*)" and "tab *varname varname2*, row" are used to summarize the characteristics of adopters and non-adopters in the sample. Bartlett's test for equal variances is obtained for continuous variables using the Stata command “oneway *varname2 varname,*” and Pearson’s chi-squared tests are obtained for discrete variables using the option “chi2.” The following characteristics are observed: demographic and socio-economic indicators (primary farmer’s gender and education level; a wealth indicator (land owned), and available household labor), farming characteristics (experience in rice cultivation, hectares of rice planted, distance to nearest agricultural extension agent or office, planting method, cropping pattern, and top sources of agricultural knowledge), pest and pesticide information (insect severity, disease severity, whether anyone in the household ever became ill from pesticide exposure), and pest management characteristics (number of IPM trainings attended, number of pesticide applications). These characteristics are summarized in Table 4.1.

Table 4.1 Farm Household Characteristics by Adoption Group

Characteristic		**Sample Non-Adopters**	**Sample Low Adopters**	**Sample High Adopters**	**Prob> Chi^2**
Province	**Takeo**	12.70% (16)	29.82% (68)	37.50% (15)	0.000***
	Prey Veng	29.37% (37)	23.68% (54)	12.50% (5)	
	Kampong Thom	22.22% (28)	28.07% (64)	15.00% (6)	
	Battambang	35.71% (45)	18.42% (42)	35.00% (14)	
Gender of primary farmer	**Male:**	57.94% (73)	50.88% (116)	52.50% (21)	0.44
	Female:	42.06% (53)	49.12% (112)	47.50% (19)	
Experience cultivating rice (years)	**Mean**	28.53	32.68	31.38	0.426
Education level	**No school:**	15.87% (20)	17.98% (41)	15.00% (6)	0.62
	Primary:	46.03% (58)	49.12% (112)	40.00% (16)	
	Secondary+:	38.10% (48)	32.89% (75)	45.00% (18)	
Household labor	**Mean:**	3.74	3.58	3.13	0.36
Distance to agricultural extension officer (km)	**Mean:**	7.83	6.92	6.50	0.027**
Land owned (ha)	**Mean:**	2.82	1.75	2.12	0.000***
Hectares of rice planted in last 12 months	**Mean:**	3.91	2.26	2.50	0.000***
Top 1st or 2nd source of agricultural	**Extension**	25.40% (32)	41.23% (94)	50.00% (20)	0.003***
	Media	14.29% (18)	21.05% (48)	32.50% (13)	0.036**
	Input suppliers	62.70% (79)	37.72% (86)	27.50% (11)	0.000***

knowledge came from…	**Personal source**	64.29% (81)	55.26% (126)	52.50% (21)	0.20
Pesticide Applications	**Mean:**	2.69	2.00	1.98	0.020**
Hired labor	**Did not hire:** **Hired:**	73.02% (92) 26.98% (34)	87.28% (199) 12.72% (29)	70.00% (28) 30.00% (12)	0.001***
Insect pest severity	**None/Low:** **Medium:** **High:**	67.46% (85) 26.19% (33) 6.35% (8)	66.23% (151) 22.37% (51) 11.40% (26)	42.50% (17) 32.50% (13) 25.00% (10)	0.006***
Disease pest severity	**None/Low:** **Medium:** **High:**	78.57% (99) 17.46% (22) 3.97% (5)	77.19% (176) 15.79% (36) 7.02% (16)	75.00% (30) 15.00% (6) 10.00% (4)	0.67
Illness from pesticide exposure	**Never been ill:** **Has been ill:**	21.43% (27) 78.57% (99)	52.63% (120) 47.37% (108)	40.00% (16) 60.00% (24)	0.000***
Planting method	**Only transplant:** **Did direct seed:**	0.00% (0) 100.00% (126)	16.67% (38) 83.33% (190)	15.00% (6) 85.00% (34)	0.000***
Cropping pattern	**Rice-fallow/other:** **Rice-Rice:** **Rice-vegetables:**	82.54% (104) 15.08% (19) 2.38% (3)	71.05% (162) 20.61% (47) 8.33% (19)	65.00% (26) 32.50% (13) 2.50% (1)	0.015**
Total		100.00% (126) 31.98% of 394	100.00% (228) 57.87% of 394	100.00% (40) 10.15% of 394	

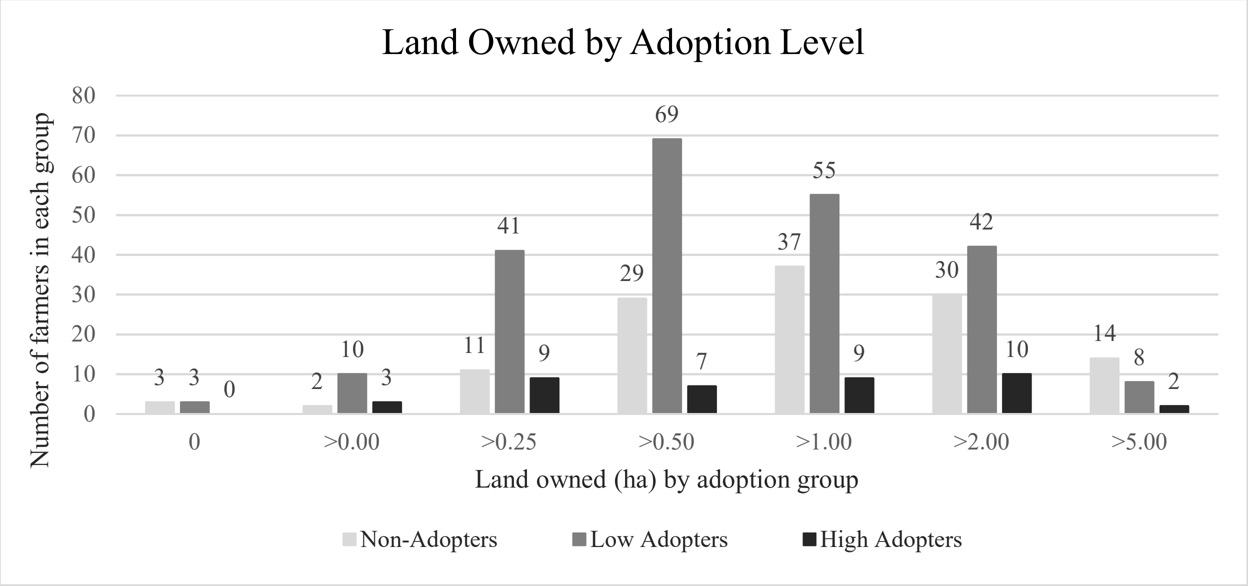
Note: Frequencies in parentheses
*****p<0.01, **p<0.05, *p<0.1**

The largest proportion (37.50%) of high adopters live in Takeo and the smallest proportion (12.50%) in Prey Veng. The largest proportion (29.82%) of low adopters live in Takeo and the smallest proportion (18.42%) in Battambang. The largest proportion (35.71%) of non-adopters live in Battambang province, the fewest (12.70%) in Takeo. The observed differences for the independence of the levels of adoption throughout the four provinces is significant at the 1% level.

Females make up a minority of all levels of adoption (47.50% of high adopters, 49.12% of low adopters, and 42.06% of non-adopters). The $\chi 2$ test for the null hypothesis that gender is independent of adoption level cannot be rejected at a statistically significant level. 40.00% of high adopters completed some primary school and 45.00% of high adopters completed some secondary school or higher; 49.12% of low adopters completed some primary school, and

32.89% of low adopters completed some secondary school or higher; and 46.03% of non-adopters completed some primary school, and 38.10% of non-adopters completed some secondary school or higher. The $\chi2$ test for the null hypothesis that educational level is independent of adoption level cannot be rejected at a statistically significant level. The mean hectares of land owned is 2.12 for high adopters, 1.75 for low adopters, and 2.82 for non-adopters. The difference in means between the three groups is significant at the 1% level. The distribution of land owned by adoption level is presented in Figure 4.3. The mean number of family members who are able to work is 3.13 for high adopters, 3.58 for low adopters, and 3.74 for non-adopters. This difference is not statistically significant.

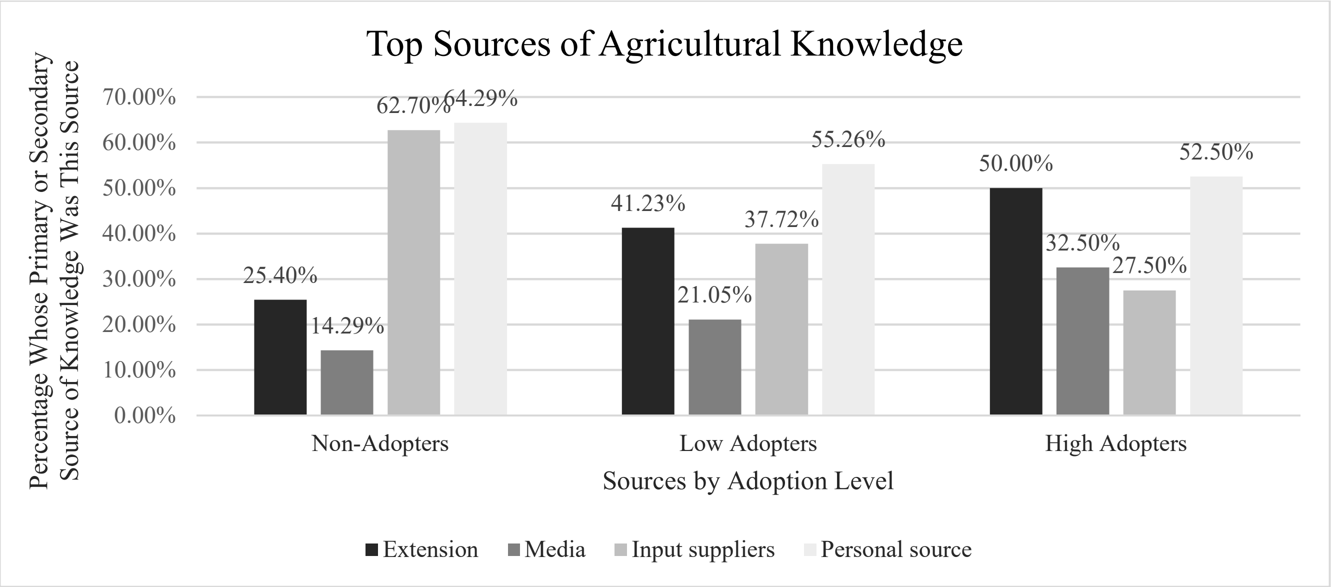
Figure 4.3 Land Owned by Adoption Level



High adopters of IPM have on average 31.38 years of experience in rice cultivation, low adopters have 32.68 years of experience, and non-adopters have 28.53 years of experience. This difference is not statistically significant. High adopters have on average 2.50 hectares of rice planted, low adopters have 2.26 hectares, and non-adopters have 3.91 hectares. This difference is significant at the 1% level. High adopters live on average 6.50 kilometers from the nearest agricultural extension worker or office, low adopters live 6.92 kilometers from the nearest worker or office, and non-adopters live 7.83 kilometers from the nearest worker or office. This difference is significant at the 5% level. 85.00% of the high adopters and 83.33% of the low adopters planted their rice using the direct seeding method, but all 126 (100.00%) of the non-adopters used direct seeding to plant their rice. The observed differences are significant at the 1% level. 65.00% of high adopters rotated their rice with fallow or other, 32.50% rotated with rice, and 2.50% rotated with vegetables. 71.05% of low adopters rotated their rice with fallow or other, 20.61% rotated with rice, and 8.33% rotated with vegetables. 82.548% of non-adopters rotated their rice with fallow or other, 15.08% rotated with rice, and 2.38% rotated with vegetables. The observed differences are significant at the 5% level.

Figure 4.4 shows that extension was one of the top two sources of agricultural knowledge for 50.00% of high adopters, 41.23% of low adopters, and 25.40% of non-adopters. The observed differences are significant at the 1% level. Media was one of the top two sources of agricultural knowledge for 32.50% of high adopters, 21.05% of low adopters, and 14.29% of non-adopters. The observed differences are significant at the 5% level. Input suppliers were one of the top two sources of agricultural knowledge for 27.50% of high adopters, 37.72% of low adopters, and 62.70% of non-adopters. The observed differences are significant at the 1% level. Personal sources were one of the top two sources of agricultural knowledge for 52.50% of high adopters, 55.26% of low adopters, and 64.29% of non-adopters. The $\chi 2$ test for the null hypothesis that agricultural knowledge from personal sources is independent of adoption level cannot be rejected at a statistically significant level.

Figure 4.4 Top Sources of Agricultural Knowledge by Adoption Level



On average, high adopters applied pesticides 1.98 times in the last twelve months, low adopters applied pesticides 2.00 times, and non-adopters applied pesticides 2.69 times. This difference is significant at the 5% level. 16.00% of high adopters hired labor to apply pesticides, 38.67% of low adopters hired labor, and 45.33% of non-adopters hired labor to apply pesticides. The observed differences are significant at the 1% level. 25.00% of high adopters experienced high severity of rice insect pests, and 32.50% of high adopters experienced medium severity of rice insect pests. 11.40% of low adopters experienced high severity of rice insect pests, and 22.37% of low adopters experienced medium severity of rice insect pests. 6.35% of non-adopters experienced high severity of rice insect pests, and 26.19% experienced medium severity. The observed differences are significant at the 1% level. 10.00% of high adopters experienced high severity of rice disease pests, and 15.00% of high adopters experienced medium severity of rice disease pests. 7.02% of low adopters experienced high severity of rice disease pests, and 15.79% of low adopters experienced medium severity of rice disease pests. 3.97% of non-adopters experienced high severity of rice disease pests, and 17.46% experienced medium severity. This difference within means is not statistically significant. 60.00% of high adopters have had someone in their household become ill from exposure to pesticides, 47.37% of low adopters have had someone in their household become ill, and 78.57% of non-adopters have had someone in their household become ill. The observed differences are significant at the 1% level.

4.1.3 Scope of IPM Training

Table 4.2 summarizes farmer responses related to receiving IPM training and sources of training. 29.70% of farmers (117) in the sample region have heard of IPM, and 22.59% (89) have received training. For farmers who received training, on average 2.88 trainings were received. Figure 4.5 shows the distribution of number of trainings received, for farmers who received IPM training. For farmers who received training, non-governmental organizations (NGOs) were the largest source with 62.92% of farmers receiving training from an NGO; 43.82% of farmers received training from the Department of Agricultural Extension (DAE), making it the second largest source; the third largest source was the Provincial Department of Agriculture (PDA), with 41.57% of farmers receiving training from PDA. Farmers also received training from National IPM Program, Department of Rice Production, General Directorate of Agriculture.

Table 4.2 IPM Training and Sources

Question	**"Yes" Responses**	**"No" Responses**	**Obs.**
Have you heard of IPM?	29.70% (117)	70.30% (277)	394
Have you received any training related to IPM?	22.59% (89)	77.41% (305)	394
How many times have you received IPM training? (Excluding zeroes)	Mean: 2.88 Min: 1 Max: 12 Std. Dev: 2.38		89
Sources of IPM Training	**"Yes" Responses**	**"No" Responses**	**Total Responses**
Dept of Ag. Extension (DAE)	43.82% (39)	56.18% (50)	89
Provincial Dept. of Ag. (PDA)	41.57% (37)	58.43% (52)	
General Directorate of Ag. (GDA)	4.49% (4)	95.51% (85)	
National IPM Program (NATIPM)	24.72% (22)	75.28% (67)	
Dept. of Rice Production (DRP)	13.48% (12)	86.52% (77)	

NGO (Ex. CEDAC, SRER Khmer)	62.92% (56)	37.08% (33)	
Private companies (PCO)	5.62% (5)	94.38% (84)	
Other	0.00% (0)	100.00% (89)	

Figure 4.5 Number of Times Farmers Received IPM Training

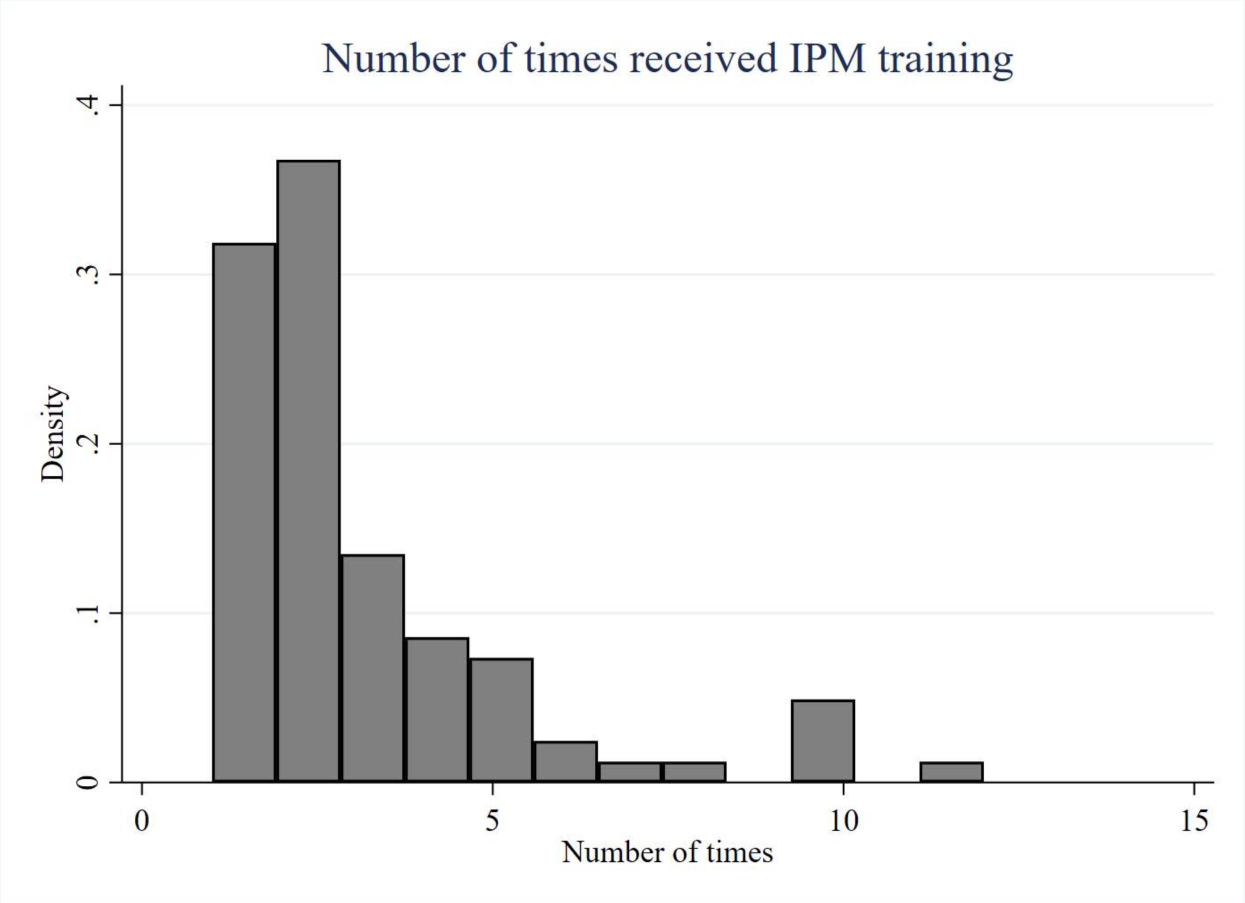


Table 4.3 shows the proportion of farmers who received IPM training by level of adoption. 18.25% of non-adopters received IPM training, 23.25% of low adopters received IPM training, and 32.50% of high adopters received IPM training. Table 4.4 shows that, on average, high adopters received 0.98 trainings on IPM, low adopters received 0.60 trainings, and non-adopters received 0.63 trainings. The difference in means between the three groups is significant at the 5% level.

Table 4.3 IPM Training Received by Adoption Level

Received IPM Training	Non-Adopters	Low Adopters	High Adopters	Total
Did not receive	81.75% (103)	76.76% (175)	67.50% (27)	77.41% (305)
Did receive	18.25% (23)	23.25% (53)	32.50% (13)	22.59% (89)
Total	100.00% (126)	100.00% (228)	100.00% (40)	100.00% (394)

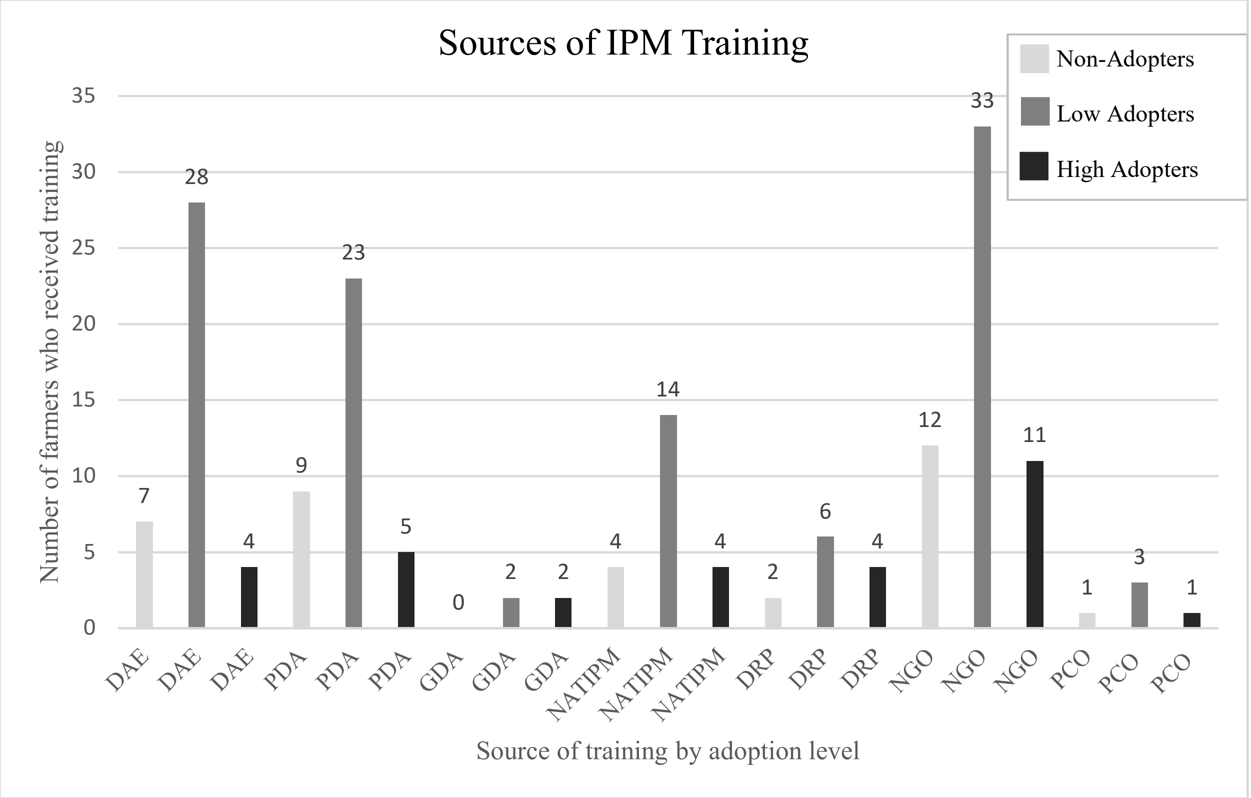
Table 4.4 IPM Training Times by Adoption Level

Number of times received IPM training	Non-Adopters	Low Adopters	High Adopters	Prob> Chi^2
Mean:	0.63	0.60	0.98	0.015**
Total	31.98% (126)	57.87% (228)	10.15% (40)	

Note: Frequencies in parentheses
*****p<0.01, **p<0.05, *p<0.1**

Figure 4.6 shows the number of farmers in each adoption level who received training by each IPM training source out of all the farmers who received training from that particular source. The most common sources of IPM training for all adoption levels were non-governmental organizations (NGOs), the Department of Agricultural Extension (DAE), and the Provincial Department of Agriculture (PDA).

Figure 4.6 IPM Training Sources by Adoption Level



4.2. Objective II: Determinants of Adoption

Two regressions were run; one for an adoption model using a dependent variable with only two levels, and one for an adoption model using a dependent variable with three levels. For the first model, where adoption was defined as using two IPM practices, and non-adoption included all other farmers, the regression resulted in only one significant variable, which indicates that there are indeed varying degrees of adoption of IPM. Thus, results will be presented and discussed for only the second model, where high adoption was defined as using two IPM practices, low adoption was defined as using one IPM practice, and non-adoption included all other farmers. Results for the first model can be found in Appendix D.4.

Results for the model are presented in Table 4.5. Experience in rice cultivation and agricultural knowledge from extension were found to positively and significantly influence both low and high levels of adoption of IPM practices. Agricultural knowledge from media was found to positively and significantly influence high adoption of IPM practices, but was not a statistically significant influence on low adoption. Household labor and agricultural knowledge from input suppliers were found to negatively and significantly affect both low and high levels of adoption of IPM practices. Female primary farmer, primary education, secondary education, distance from agricultural extension office, land owned, hectares of rice planted, number of IPM trainings received, and agricultural information from personal sources were not found to be significant factors influencing high or low levels of adoption.

Table 4.5 Adoption Results

ADOPT	**Coef.**	**Std. Error**	**z**	**P>|z|**	**Marginal Effects**	**Marginal Effects P>|z|**
Outcome 1 (Low adoption)						
FEMALE	0.39	0.27	1.43	0.15	0.043	0.40
EXP	0.33	0.10	3.29	0.001***	0.0057	0.003***
EDUCPRIM	0.13	0.35	0.38	0.70	0.026	0.71
EDUCSEC	-0.32	0.38	-0.83	0.40	-0.069	0.37
HSHLDLABOR	-0.14	0.081	-1.68	0.094*	-0.0065	0.69
DISTANCE	-0.027	0.23	-1.16	0.25	-0.0033	0.49
LANDOWNED	-0.076	0.77	-0.98	0.33	-0.021	0.22
HECTARESRICE	-0.0094	0.046	-0.20	0.84	0.0012	0.91
TRAININGTIMES	-0.061	0.094	-0.65	0.52	-0.023	0.16
FEMALE* TRAININGTIMES	-0.094	0.16	-0.59	0.56		
EXTENSION	0.92	0.36	2.52	0.012**	0.11	0.10
MEDIA	0.47	0.38	1.22	0.22	0.016	0.83
INPUTSUPPLIERS	-0.70	0.27	-2.55	0.011**	-0.11	0.057*
PERSONALSOURCE	0.15	0.32	0.48	0.63	-0.00040	0.995
_constant	0.26	0.70	0.37	0.71		
Outcome 2 (High adoption)						
FEMALE	0.52	0.45	1.17	0.24	0.022	0.50
EXP	0.029	0.015	1.91	0.057*	0.00047	0.68
EDUCPRIM	0.056	0.59	0.10	0.92	-0.0034	0.94
EDUCSEC	-0.045	0.61	-0.07	0.94	0.015	0.75
HSHLDLABOR	-0.39	0.15	-2.67	0.008***	-0.025	0.030**
DISTANCE	-0.045	0.039	-1.13	0.26	-0.0022	0.48
LANDOWNED	0.064	0.13	0.49	0.63	0.010	0.36

HECTARESRICE	-0.055	0.094	-0.58	0.56	-0.0042	0.60
TRAININGTIMES	0.027	0.13	0.21	0.83	0.0064	0.46
FEMALE* TRAININGTIMES	-0.063	0.22	-0.29	0.78		
EXTENSION	1.39	0.55	2.53	0.012**	0.068	0.15
MEDIA	1.19	0.54	2.19	0.029**	0.089	0.11
INPUTSUPPLIERS	-0.86	0.47	-1.80	0.072*	-0.032	0.37
PERSONALSOURCE	0.56	0.50	1.13	0.26	0.039	0.30
_constant	-1.33	1.14	-1.16	0.25		

***p<0.01, **p<0.05, *p<0.1

The effect of years of experience in rice cultivation on the probability of low adoption is positive and significant at the 1% level. One additional year of experience in rice cultivation increases the probability of adoption by 0.57 percentage points. This confirms our expectation that experienced farmers better understand their rice production and pest management as compared with less-experienced farmers, and are more likely to use integrated pest management rather than rely solely on chemical pesticides to manage pests.

The negative effect of household labor on low adoption is significant at the 10% level; however, the marginal effect of increasing the household size by one additional family member on the probability of low adoption is not statistically significant. The sign and marginal effect of household labor on the probability of high adoption are both significant. The effect of household labor on high adoption is negative and significant at the 1% level. The marginal effect of increasing the household size by one additional family member decreases the probability of high adoption by 2.5 percentage points and is significant at the 5% level. This effect is contrary to our prediction that household labor increases the probability of adoption. Kabir & Rainis (2015) offer an explanation for this contradiction; additional laborers in the family often work off the farm to diversify risk and supplement household income. Table 4.6 shows that 251 respondents in our survey have a primary or secondary occupation besides agriculture.

Table 4.6 Primary and Secondary Occupation

Occupation	Agriculture	Business	Wage job	Other	No 2nd Occ.	Total
Primary Occupation	97.72% (385)	1.27% (5)	0.76% (3)	0.25% (1)	N/A	100.00% (394)
Secondary Occupation	2.28% (9)	37.56% (148)	22.59% (89)	1.27% (5)	36.29% (143)	100.00% (394)
Total	100.00% (394)	38.83% (153)	23.35% (92)	01.52% (6)	36.29% (143)	N/A

The positive influence of agricultural information from extension on both low and high adoption is significant at the 5% level; however, the average partial effect of receiving agricultural information from extension on the probability of low or high adoption is not statistically significant. The positive influence of agricultural information from media on high adoption is significant at the 5% level; however, the average partial effect of receiving agricultural information from media on the probability of high adoption is not statistically significant. The effect of agricultural information from media on low adoption is not statistically significant. The effect of agricultural information from input suppliers on the probability of low adoption is negative and significant at the 5% level. The average partial effect of receiving agricultural information from media decreases the probability of adoption by 5.7 percentage points. The negative influence of agricultural information from input suppliers on high adoption is significant at the 10% level; however, the average partial effect of receiving agricultural information from input suppliers on the probability of high adoption is not statistically significant. The effects of agricultural information from a personal source on both low and high adoption are positive but not statistically significant. These findings are all consistent with our expectations.

Compared with having a male primary farmer, the effects of having a female primary farmer on the probability of low or high adoption of IPM are positive but not statistically significant. This sign is consistent with our expectations. Table 4.7 shows who decides what to do when pest problems occur, by adoption level. For non-adopters, 43.65% of the decision-makers are male, 28.57% are female, and 16.67% are shared between both spouses equally. For low adopters, 23.68% of the decision-makers are male, 12.28% are female, and 21.93% are shared between both spouses equally. 40.35% of low adopters responded that no one decides what to do when pest problems occur. For high adopters, 27.50% of the decision-makers are male, 22.50% are female, and 22.50% are shared between both spouses equally. The Pearson $\chi 2$ test shows that the observed differences between the rows and columns are significant at the 1% level. However, the Bartlett test for equal variances shows that the difference in adoption level between male primary decision-makers and female primary decision-makers is not statistically significant.

Table 4.7 Person Who Decides What to Do When Pest Problems Occur

Adoption Level	Husband or Male Head	Wife or Female Head	Both Spouses Equally	Other	No One	Total
Non	43.65% (55)	28.57% (36)	16.67% (21)	2.38% (3)	8.73% (11)	100.00% (126)
Low	23.68% (54)	12.28% (28)	21.93% (50)	1.75% (4)	40.35% (92)	100.00% (228)
High	27.50% (11)	22.50% (9)	22.50% (9)	7.50% (3)	20.00% (8)	100.00% (40)

Compared with no education, the effects of primary education on the probability of low or high adoption are positive but not statistically significant. Compared with no education, the effects of secondary education on the probability of low or high adoption are negative but not statistically significant. This makes sense because the difference in education levels within the adoption levels is not statistically significant (see Table 4.1). Because the education level for high adopters, low adopters, and non-adopters is similar, one group is not necessarily more knowledgeable than the other about farming, pest management, or decision-making.

The effects of distance from agricultural extension office on the probability of low or high adoption are negative but not statistically significant. This sign is consistent with our expectations.

The effect of wealth, as measured by land owned, on the probability of low adoption is negative but not statistically significant. The effect of wealth on the probability of high adoption is positive but not statistically significant. This finding is not surprising, as IPM literature is mixed on the effect of household wealth on adoption (Abdollahzadeh, Damalas, and Sharifzadeh, 2017; Haque, Kabir, and Nishi, 2016; and Kabir & Rainis, 2015).

The effects of hectares of rice planted on the probability of low or high adoption are negative but not statistically significant. One explanation for the negative sign is that some IPM practices are time- and labor-consuming, and farmers who plant more hectares of rice do not necessarily have more time or labor resources to spend compared farmers who plant fewer hectares of rice.

The effect of training times on the probability of low adoption is negative but not statistically significant. The effect of training times on the probability of high adoption is positive but not statistically significant. We expected training times to be positive and significant factors influencing low and high levels of adoption because IPM trainings increase exposure to and knowledge about IPM. The insignificance of the effect of training times on adoption can be explained by examining the significances of the differences in mean training times between groups. The Bonferroni-adjusted significance level is calculated in Stata using the option "bonferroni" after conducting the oneway ANOVA test. The Bonferroni-adjusted significance of the difference in training times between adoption levels 0 and 1 is 1.00, the significance of the difference in training times between adoption levels 1 and 2 is 0.56, and significance of the difference in training times between adoption levels 0 and 2 is 0.77. Because the differences in training times between adoption levels are not significant, it is understandable for training times to not have a significant effect on the likelihood of adoption.

Bartlett's test for equal variances revealed some significance in the mean number of training times for the use of certain IPM practices – pest-resistance variety, stale seedbed, bio-pesticides. For those IPM practices, as well as for the group of farmers who did not use pesticides but also did not specify any practices, there was a significant difference in the mean number of training times between farmers who used the practices and farmers who did not use the practices (see Table 4.8).

Table 4.8 IPM Practices Used by Number of Training Times

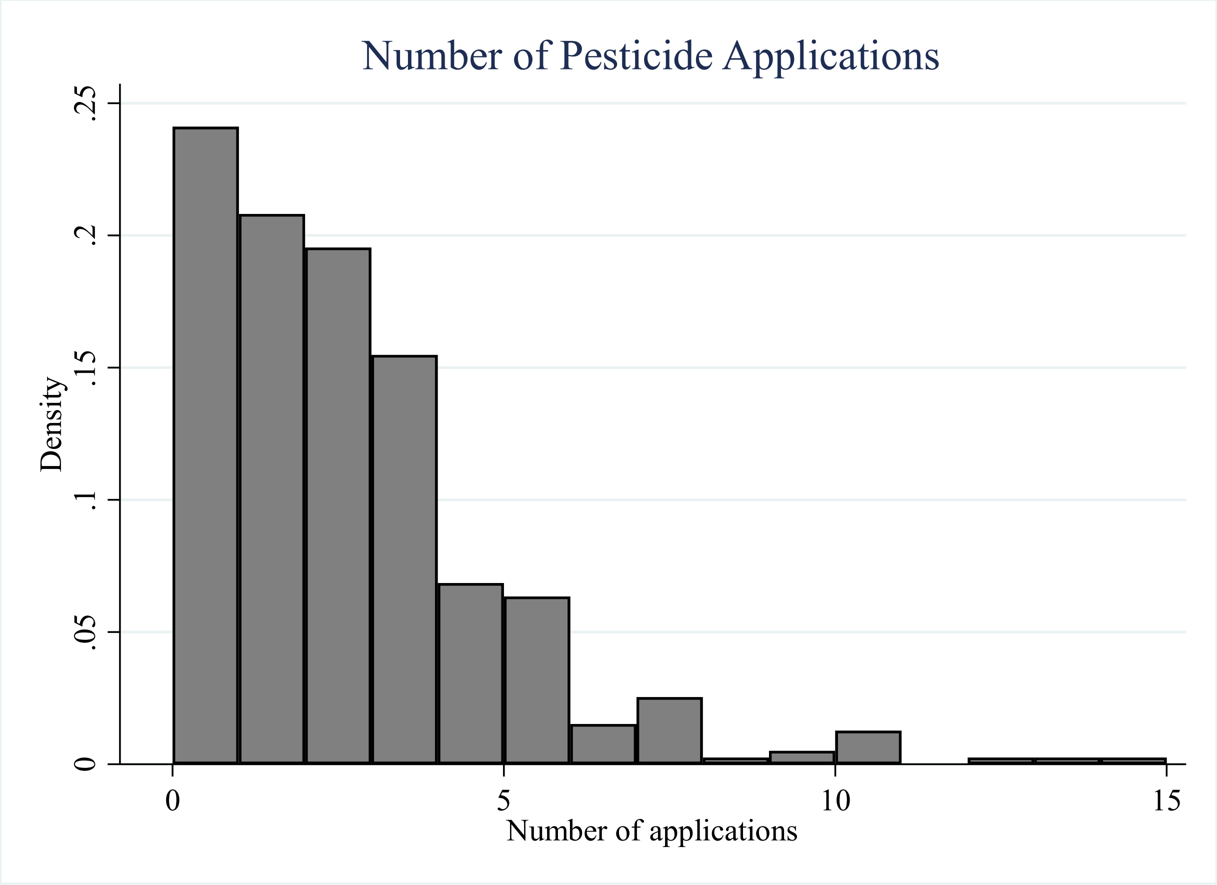
	Average Training Times (Frequency)		**One-way ANOVA test**
IPM Practice	**Farmers who did not use practice**	**Farmers who did use practice**	**Prob > Chi2**
Pest-resistant variety A1	0.64 (385)	0.89 (9)	0.000
Stale seedbed B2	0.64 (391)	1.33 (3)	0.000
Trichoderma C3	0.65 (394)	N/A (0)	N/A
No spray for 40 days D4	0.66 (340)	0.59 (54)	0.87
Bio-pesticides E5	0.64 (392)	3.00 (2)	0.011
***Sarcocystis* bait for rodents F6**	0.65 (392)	0.00 (2)	N/A
Hand weeding G7	0.54 (183)	0.74 (211)	0.97
Other H99	0.65 (394)	N/A (0)	N/A
None I0	0.67 (239)	0.62 (155)	0.89
No pesticides, no practices J8	0.66 (365)	0.55 (29)	0.004

The effects of the interaction between female and training times on the probability of low and high adoption are negative but not statistically significant. We expected female*training times to be a positive factor influencing low and high levels of adoption because IPM trainings increase exposure to and knowledge about IPM and females are protective of their families' health.

4.3. Objective III: Effect of Adoption on Pesticide Usage

In total, 299 farmers applied pesticides to their rice during the last twelve months. On average, those farmers applied pesticides 2.92 times, with a standard deviation of 2.18, a maximum of 15 applications, and a median of 2 applications. The distribution of pesticide applications is shown in Figure 4.7.

Figure 4.7 Distribution of Pesticide Applications



Results for the pesticide model are presented in Table 4.9. Hectares of rice, hire labor, illness, and direct seeding were found to positively and significantly affect the number of pesticide applications. Rice-fallow cropping pattern was found to negatively and significantly affect the number of pesticide applications. Adoption level, female primary farmer, experience, education level, wealth (represented by land owned), sources of agricultural knowledge, level insect severity, and rice-vegetable cropping pattern were not found to be significant factors influencing pesticide use.

Table 4.9 Pesticide Applications Results

PESTICIDEUSE	**Coef.**	**Std. Error**	**t**	**P>|t|**
ADOPTLOW	0.20	0.23	0.87	0.39
ADOPTHIGH	-0.18	0.36	-0.48	0.63
FEMALE	0.18	0.21	0.85	0.40
EXP	-0.0073	0.078	-0.94	0.35
EDUCPRIM	-0.31	0.28	-1.10	0.27
EDUCSEC	-0.33	0.30	-1.10	0.27
LANDOWNED	-0.015	0.064	-0.23	0.82
HECTARESRICE	0.11	0.040	2.67	0.008***
EXTENSION	-0.12	0.27	-0.44	0.66
MEDIA	-0.31	0.29	-1.07	0.29
INPUTSUPPLIERS	0.36	0.24	1.52	0.13
PERSONALSOURCE	0.041	0.25	0.17	0.87
HIRELABOR	0.51	0.25	2.04	0.042**
INSECTSMED	0.094	0.25	0.37	0.71
INSECTSHIGH	-0.065	0.35	-0.19	0.85
ILLNESS	1.51	0.23	6.50	0.000***
DIRECTSEED	1.01	0.34	3.01	0.003***
CROPFALLOW	-1.45	0.27	-5.44	0.000***
CROPVEG	-0.66	0.47	-1.42	0.16
_constant	1.40	0.69	2.05	0.042

*** p<0.01, ** p<0.05, * p<0.1

The effect of hectares of rice on the number of pesticide applications is positive and significant at the 1% level. Increasing the amount of rice planted by one additional hectare increases the number of pesticide applications by 0.11. This confirms our prediction that more land requires a higher number of pesticide applications.

The effect of hired labor on the number of pesticide applications is positive and significant at the 5% level. Farmers who hired labor to apply pesticides applied on average 0.51 more pesticides than farmers who did not hire labor. This response is consistent with our prediction.

The effect of illness on the number of pesticide applications is positive and significant at the 1% level. If any of the household members ever fell ill from pesticide exposure, the number of pesticide applications higher by 1.51 compared to farmers who had no one in their household fall ill due to pesticide exposure. The positive sign can be explained by the fact that having someone in the household fall ill due to pesticide exposure necessitates the members of the household having previously used or been exposed to pesticides. Table 4.10 shows that out of farmers who had someone in their households fall ill from pesticide exposure, only 2.16% did not apply pesticides in the past 12 months.

Table 4.10 Illness from Pesticide Exposure by Use of Pesticides

Someone in the family became ill from pesticide exposure	**Did not apply pesticides in the past 12 months**	**Applied pesticides in the past 12 months**	**Total**
No one ever became ill	55.21% (90)	44.79% (73)	100.00% (163)
Someone became ill	2.16% (5)	97.84% (226)	100.00% (231)
Total	24.11% (95)	75.89% (299)	100.00% (394)

The effect of direct seeding on the number of pesticide applications is positive and significant at the 1% level. Farmers who planted their rice by direct seeding, instead of or in addition to transplanting rice, on average apply 1.01 more pesticides compared with farmers who planted their rice by transplanting alone. This effect is consistent with our prediction that farmers who direct seed their rice have less control over weed growth and must apply pesticides to manage weeds rather than weeding by hand.

The effect of using a rice-fallow or rice-other cropping pattern is negative and significant at the 1% level. The use of a rice-fallow cropping pattern decreases the number of pesticide applications by 1.45 compared with a rice-rice cropping pattern. The effect of using a rice-vegetable cropping pattern is negative but not statistically significant. These confirm our prediction that rice-rice cropping patterns would require a higher number of pesticide applications compared with other cropping patterns due to an association with higher pest severity. Table 4.11 shows that a rice-rice cropping pattern is associated with higher pest severity than other cropping patterns; only 13.04% of rice-vegetable farmers and 7.19% of rice-fallow or rice-other farmers had high insect severity, whereas 25.32% of rice-rice farmers had high insect severity.

Table 4.11 Cropping Pattern by Insect Severity

Cropping pattern	**None/low**	**Medium**	**High**	**Total**
Rice-fallow or Rice-other	71.92% (210)	20.89% (61)	7.19% (21)	100.00% (292)
Rice-vegetables	56.52% (13)	30.43% (7)	13.04% (3)	100.00% (23)
Rice-rice	37.97% (30)	36.71% (29)	25.32% (20)	100.00% (79)
Total	64.21% (253)	24.62% (97)	11.17% (44)	100.00% (394)

Compared with non-adoption, the effect of low adoption of IPM on the number of applications of pesticides is positive but not statistically significant. The effect of high adoption of IPM, compared with non-adoption, on the number of applications of pesticides is negative but not statistically significant. The signs on both low adoption and high adoption were expected to be negative; as farmers use alternative forms of pest management, they rely less on pesticides. Figure 4.8 shows the distribution of pesticide applications by adoption level, and Table 4.12 summarizes the number of pesticide applications by adoption level. 77.0% of non-adopters applied pesticides one or two, or three times, and 67.5% of high adopters applied pesticides one, two, or three times, while only 42.1% of low adopters applied pesticides one, two, or three times. The Bonferroni-adjusted significance of the difference in pesticide applications between non-adoption (2.69 pesticide applications on average) and low adoption (2.00 pesticide applications on average) is 0.018, the significance of the difference in pesticide applications between non-adoption and high adoption (1.98 pesticide applications on average) is 0.24, and significance of the difference in pesticide applications between low adoption and high adoption is 1.00. Based on these observations, it makes sense that the effect of high adoption on pesticide applications is not significant, but we would expect the effect of low adoption on pesticide applications to be significant.

Figure 4.8 Pesticide Applications by Adoption Level

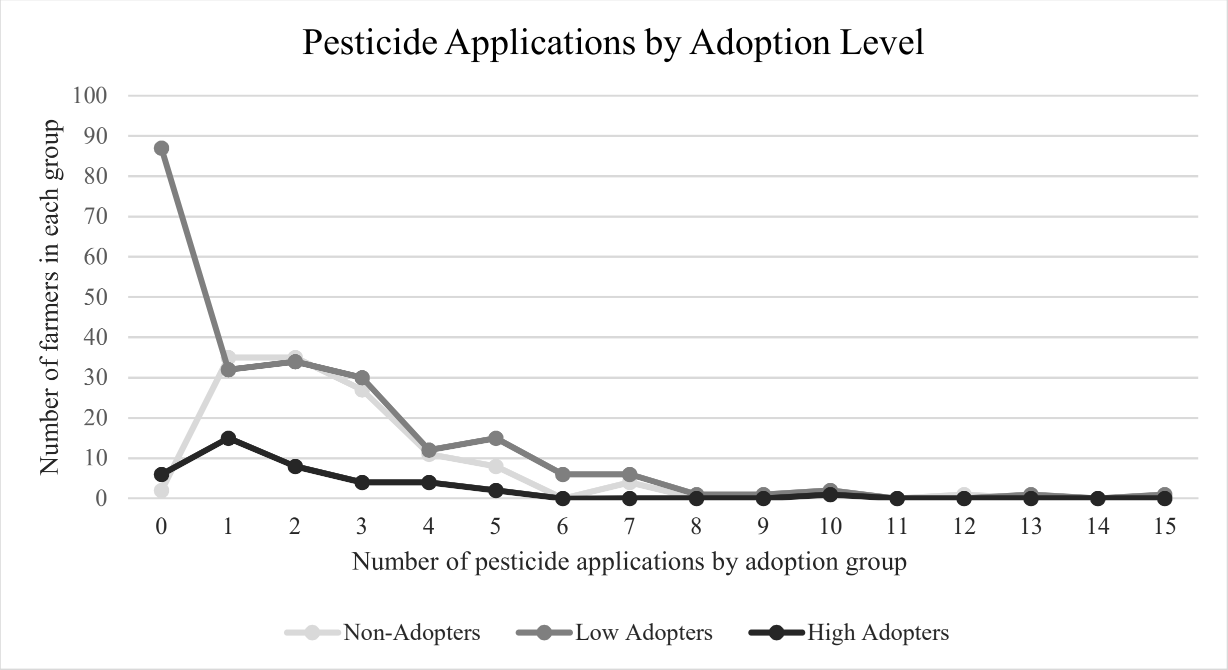


Table 4.12 Adoption Level by Pesticide Applications

Adopt Level	0	1	2	3	4	5	6	7	8	9	10	12	13	15	Total
Non	**1.6**	**27.8**	**27.8**	**21.4**	**8.7**	**6.4**	**0.0**	**3.2**	**0.0**	**0.8**	**1.6**	**0.8**	**0.0**	**0.0**	**100.0**
Low	**38.2**	**14.0**	**14.9**	**13.2**	**5.3**	**6.6**	**2.6**	**2.6**	**0.4**	**0.4**	**0.9**	**0.0**	**0.4**	**0.4**	**100.0**
High	**15.0**	**37.5**	**20.0**	**10.0**	**10.0**	**5.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.5**	**0.0**	**0.0**	**0.0**	**100.0**

Note: Row percentages are shown.

The effect of having a female primary farmer, compared to having a male primary farmer, on the number of pesticide applications is positive but not statistically significant. We suspected that female farmers who apply pesticides would apply fewer pesticides than male farmers. However, based on Bonferroni's adjusted significance test (see Table C.1 in Appendix C), there is no statistically significant difference between the number of pesticide applications by gender of person who generally applies pesticide or pest management products; thus, we cannot conclude that females apply fewer pesticides than males.

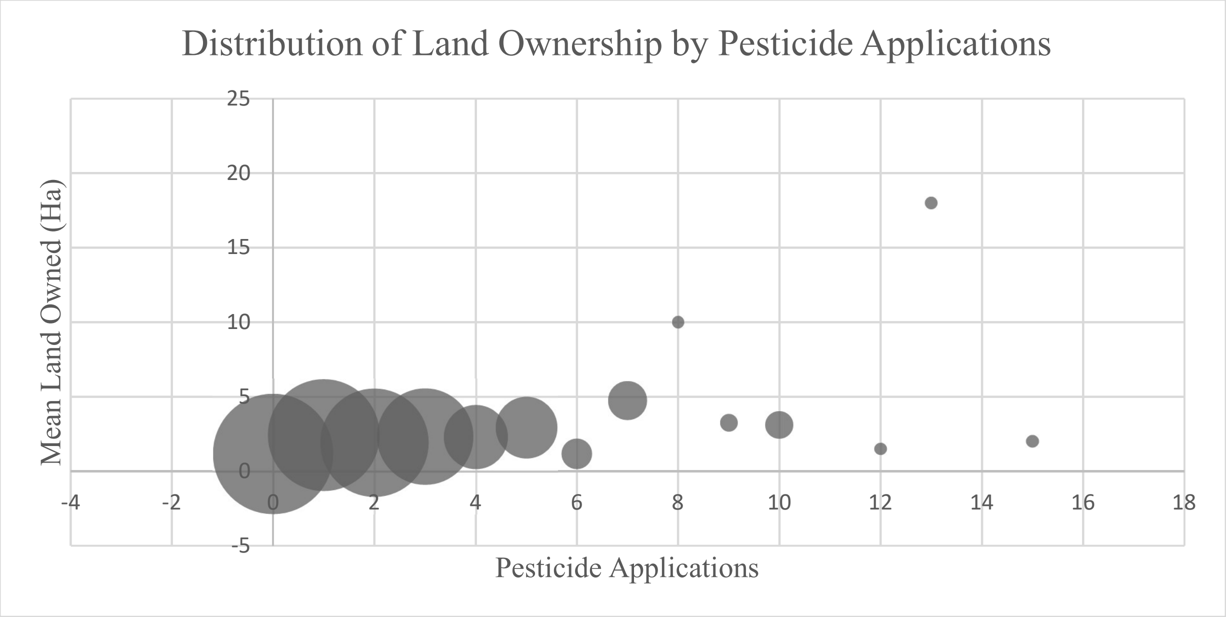
The effect of experience on the number of applications of pesticides is negative but not statistically significant. This sign is consistent with our prediction that farmers with more experience have better understanding of the level of pesticides needed to maintain yield, and thus would not over-apply them.

The effect of education on the number of applications of pesticides is negative but not statistically significant. This sign is consistent with our prediction that educated farmers have more knowledge, which leads them to apply the proper amount of pesticides needed to maintain yield, rather than over-applying them.

The effect of wealth (as measured by hectares of land owned) on the number of applications of pesticides is negative but not statistically significant. We predicted that farmers with greater wealth can afford to buy more pesticides than less-wealthy farmers. The Bonferroni adjusted significance test shows that the difference in land ownership between farmers who applied zero pesticides and farmers who applied pesticides one or more times is only significant for farmers who applied pesticides seven times and farmers who applied pesticides thirteen times (see Appendix D.5). There is no statistical difference in hectares of land owned between farmers who applied pesticides other numbers of times and those who applied pesticides zero times. As

Figure 4.9 (and corresponding Table C.2 in Appendix C) demonstrates, the average amount of land owned for farmers who applied pesticides seven and thirteen times are outliers. Thus, wealth, as demonstrated by land ownership, was not a determinant of pesticide applications for sample farmers in our model.

Figure 4.9 Distribution of Land Ownership by Pesticide Applications



This observation can be explained by examining the credit constraint faced by farmers in our sample; only one of the farmers in our sample faced a credit constraint. Out of the 394 farmers in our sample, 25.89% (102) needed to borrow money to finance their rice production. Out of those farmers, all but one was able to borrow the amount they needed (that farmer planted 0.50 hectares of rice and applied pesticides twice). In fact, those who borrowed money applied more pesticides on average. Borrowers applied pesticides 3 times on average, whereas non-borrowers applied pesticides an average of 1.94 times; this difference in means is significant at the 5% level according to the one-way ANOVA test. The ability to borrow money enabled farmers in our sample to purchase the amount of pesticides they desired regardless of their wealth level.

The effects of top source of agricultural information from extension and from media are negative but not statistically significant. The effects of top source of agricultural information from input suppliers and from personal sources are negative but not statistically significant. These signs are consistent with our expectations. The difference in means of the number of pesticide applications is only significant for INPUTSUPPLIERS (Pr(|T|>|t|) is 0.0011; Table 4.13). Based on these observations, we would expect input suppliers to significantly influence the number of pesticide applications.

Table 4.13 Agricultural Knowledge Sources and Pesticide Applications

Knowledge Source	Mean Pesticide Applications	Freq	T (df)	Pr(|T|>|t|)
EXTENSION	Top source was not extension: 2.27 Top source was extension: 2.13	248 146	0.59 (392)	0.56
MEDIA	Top source was not media: 2.29 Top source was media: 1.94	315 79	1.23 (392)	0.22
INPUTSUPPLIERS	Top source was not input suppliers: 1.89 Top source was input suppliers: 2.63	218 176	-3.28 (392)	0.0011
PERSONALSOURCE	Top source was not a personal source: 2.05 Top source was a personal source: 2.34	166 228	-1.22 (392)	0.22

The effect of medium insect severity on the number of applications of pesticides is positive but not statistically significant. The effect of high insect severity on the number of applications of pesticides is negative but not statistically significant. Insect severity was expected to have a positive effect on the number of pesticide applications because greater pest severity requires more pest control. However, Table 4.14 shows that most of the farmers in our sample applied pesticides regardless of the level of insect pest severity on their rice farms. A smaller proportion of farmers (67.98% of 253) with no or low insect severity applied pesticides than did farmers with medium severity (90.72% of 97) or high severity (88.64% of 44), but a majority still applied pesticides even though they had a lower severity of insects.

Table 4.14 Insect Severity by Use of Pesticides

Insect Severity	**Did not apply pesticides in the past 12 months**	**Applied pesticides in the past 12 months**	**Total**
None/Low	32.02% (81)	67.98% (172)	100.00% (253)
Medium	9.28% (9)	90.72% (88)	100.00% (97)
High	11.36% (5)	88.64% (39)	100.00% (44)
Total	24.11% (95)	75.89% (299)	100.00% (394)

5. Chapter 5: Conclusions

The objectives of this study were to 1) establish a baseline for the EPIC project by observing the proportion of rice IPM adopters in the region and exploring the characteristics of adopters, frequency and type of IPM practices adopted, and scope of IPM training in the region; 2) analyze the determinants of IPM adoption, in particular, gender, IPM training, and agricultural knowledge source; and 3) analyze the effect of IPM adoption on pesticide usage.

The first objective was accomplished in Section 4.1. When creating the rice IPM package for Cambodia, EPIC should be aware that intensity of adoption throughout the four provinces was low - only 40 farmers (10.15%) out of the sample of 394 adopted more than one IPM practice; no farmers adopted more than two practices. Hand weeding dominated out of all the IPM practices adopted; hand weeding was one of, if not the only, rice IPM practice employed by 211 (78.73%) of the 268 adopters. Very few IPM practices besides hand weeding and no spray for 40 days were adopted by the farmers in our sample. Only 14 farmers (3.55%) used an IPM practice other than hand weeding or no spray for 40 days; these other practices were pest-resistant variety, stale seedbed, bio-pesticides, and *Sarcocystis* bait for rodents. Out of the practices we enquired about in the household survey, Trichoderma was not adopted by anyone in the sample. No farmer mentioned the use of any practice not listed on the household survey. Because few other IPM practices were adopted, it may take a long time for practices such as pest-resistant variety, stale seedbed, bio-pesticides, *Sarcocystis* bait, and Trichoderma to be adopted fully throughout the region.

Trainings on IPM throughout the region were occasionally received by farmers, though a significant proportion of adopters did not receive IPM training at all. Only 32.50% of high adopters and 23.25% of low adopters received training on IPM; in total, only 22.59% of farmers

(89) received training on IPM. 29 farmers (34.94%) of the 83 farmers who used the practice “no spray for 40 days,” did not report using this practice because they used no pesticides at all; because they did not respond positively to adopting any IPM practices in the household survey, their understanding of adoption of IPM may be very limited. Indeed, 25 farmers of this group did not receive any IPM trainings; the remaining four farmers each received a total of 1, 2, 5, and 8 trainings, respectively. If EPIC utilizes IPM training programs, it should ensure that farmers come away from trainings with a greater understanding of rice IPM practices and implementation of practices.

Some farmers who received training on IPM did not adopt any IPM practices; out of the 89 farmers who received IPM training, 25.84% (23) of them were non-adopters. In fact, non-adopters received on average more IPM trainings (0.63 trainings) than low adopters (0.60 trainings), though high adopters received significantly more than either of the two groups (0.98 trainings). Because the reception of IPM training does not guarantee adoption, EPIC should ensure that IPM trainings reach a broad number of farmers in order to achieve maximum adoption in the region.

The portrait of a statistically average high adopter lives in Takeo, is male, has 31.38 years of experience in rice cultivation, has some secondary education, lives 6.50 kilometers from the nearest agricultural extension officer, owns 2.12 hectares of land, and planted 2.50 hectares of rice in the last 12 months. EPIC can use this portrait to seek out other early adopters from whom they may be able to record testimonials with which to promote the new IPM rice package.

The second objective was accomplished in Section 4.2. Greater experience in rice cultivation and considering extension as a top source of agricultural knowledge were identified as significant factors that, all other factors held constant, increase the likelihood of low adoption.

Experience in rice cultivation and considering extension or media as a top source of agricultural knowledge were identified as significant factors that, all other factors held constant, increase the likelihood of high adoption. Greater number of household members who are able to work and considering input suppliers as a top source of agricultural knowledge were identified as significant factors that, all other factors held constant, decrease the likelihood of low or high adoption. In order to increase adoption of the upcoming IPM package, EPIC should consider targeting farmers who have greater experience in rice cultivation, fewer number of household members who are able to work, and who consider extension or media as a top source of agricultural knowledge, as these individuals are more likely to adopt IPM.

Receiving a higher number of trainings on IPM was not found to be a significant factor influencing adoption in our study, though several other empirical studies on adoption of rice IPM found IPM training to have a significant positive effect on adoption.

In order to promote the upcoming rice IPM package, EPIC should communicate through the means that are most likely to influence farmers to adopt IPM. Thus, we recommend the use of extension and media, rather than personal sources, as the primary means through which to encourage farmers to adopt IPM. The mostly highly recommended means by which to communicate through extension are government agricultural extension workers and NGO agricultural extension workers; only 12 farmers attended a field day or farmer field school in the past two years, and only one adopter considered farmer field school a top source of agricultural knowledge (see Tables C.3. and C.4 in Appendix C). The mostly highly recommended specific forms of media are radio and video; few farmers received information from newspapers, mobile phone messages, and social media, or considered them a top source of knowledge (see Tables C.3. and C.4 in Appendix C).

Though we found the effects of having a female primary farmer on the probability of low or high adoption of IPM to be positive but not statistically significant, EPIC should ensure gender equity in the program by targeting female farmers. Not surprisingly, female primary farmers make up a minority in each level of adoption; however, 47.50% of high adopter primary farmers and 49.12% of low adopter primary farmers in our sample were female. It is the female head alone, or the wife together with her husband, who decides what to do when pest problems occur for 45.00% of high adopters and 34.21% of low adopters. It is the female head alone, or the wife together with her husband, who decides how to spend money earned from selling rice for 33.25% of all farmers. In addition, women are involved in pest management activities; 24.45% of all farmers who buy pesticides or pest management products are women, 19.29% of farmers who decide how much to spend on pesticides or pest management are women, 26.14% of farmers who mix pesticides are women, and 25.89% of farmers who apply pesticides or pest management products are women.

Despite the fact that 38.83% of women are involved in making decisions regarding what to do when pest problems occur, only 21.98% of IPM training attendees were women. Being a female who received IPM training did not have a statistically significant effect on adoption, but because women play an important role in pest management decision-making, EPIC should certainly target female farmers in IPM trainings in order to ensure gender parity among the recipients of training opportunities.

The third objective was accomplished in Section 4.3. On average, the 299 farmers who applied pesticides to their rice during the past year applied pesticides 2.92 times. Neither low nor high adoption were found to significantly influence the number of pesticide applications. We expected both low adoption and high adoption to have a negative and significant influence on pesticide applications; we expected that as farmers use alternative forms of pest management, they rely less on pesticides.

In the last 5-10 years, 30.96% of farmers increased their use of pesticides on rice (see Table C.5. in Appendix C). We found that a majority of farmers applied pesticides regardless of their level of insect severity; this turns out to be true for the level of disease severity as well (see Table C.6 in Appendix C). However, when the 134 farmers who increased or decreased their use of pesticides over the last 5-10 years were asked why their pesticide use had changed, 30.60% (41) said that it was because they had more or fewer pests (Table C.7 in Appendix C).

A slightly larger proportion (15.38%) of high adopters had women or children in their family who became ill from pesticide exposure compared to low adopters (7.02%) or non-adopters (8.00%), though this difference is not statistically significant (see Table C.8 in Appendix C and Appendix D.6). Surprisingly, when women are responsible for applying pesticides, they apply more pesticide sprays on average (3.22 applications) than men alone (2.91 applications) (see Table C.9 in Appendix C). Further, when women are responsible for decision-making regarding pest problems, they apply more times on average (3.22 applications) than men alone (2.61 applications) (see Table C.10 in Appendix C). This is in contrast to the very slight difference between average number of pesticide applications by female primary farmers (2.217) and male primary farmers (2.219). Upon further examination we see that female primary farmers have completed less schooling than male primary farmers (see Table C.11 in Appendix C). 27.17% of female primary farmers have no education, and only 24.46% have some secondary education or higher, whereas only 8.10% of male primary farmers have no education, and 45.71% have some secondary education or higher (the difference in education levels between genders is significant at the 1% level; see Appendix D.7). This finding suggests that perhaps women apply more pesticides because they are less educated about pest management or less knowledgeable in general about pest management.

We observed that the largest proportion of both high and low adopters in our sample live in Takeo province, whereas the smallest proportion of non-adopters reside in Takeo. Likewise, the smallest proportion of low adopters live in Battambang, while the largest proportion of non-adopters live in that same province. Table C.12 (in Appendix C) shows that 63.64% of Takeo residents applied pesticides in the last 12 months, while an overwhelming 94.06% of Battambang residents applied pesticides. This is noteworthy because only 1.98% of farmers in Battambang province reported a high severity of insects; 69.31% of Battambang farmers reported no or low insect severity (see Table C.13 in Appendix C). In contrast, 22.22% of farmers in Takeo province reported high insect severity. These observations indicate a significant need for IPM education in Battambang province.

In conclusion, this study provides information and important determinants of adoption for the EPIC program to use as a baseline as a rice IPM package is formulated, distributed, and promoted throughout the Takeo, Prey Veng, Kampong Thom, and Battambang provinces of Cambodia. We found that IPM practices currently include mostly hand-weeding; IPM has not spread much throughout Cambodia yet, and not many other practices have been adopted at this point in time. Out of 394 farmers, 40 adopted more than one IPM practice, 228 adopted one IPM practice, and the remaining 126 adopted zero IPM practices. There is a need for increased knowledge of IPM in the country, as evidenced by the fact that less than one-quarter of farmers in our study have received training on IPM.

Greater experience in rice cultivation and fewer number of household members who are able to work are both factors that increase the probability of adoption; EPIC should target farmers who have these characteristics in order to increase adoption of IPM. EPIC should use extension and media as the primary means through which to promote the upcoming rice IPM package, as these are the means which are most likely to influence farmers to adopt IPM. Though IPM trainings were not significant influences on adoption for farmers in our study, the top sources of trainings on IPM were received from non-governmental organizations (NGOs), the Department of Agricultural Extension (DAE), and the Provincial Department of Agriculture (PDA); thus, we recommend that EPIC use these sources of training to further promote adoption.

Though female primary farmer was not found to be a statistically significant factor influencing adoption or pesticide applications, women were found to be important agents in regard to pest management decision-making and pesticide application. EPIC should target female farmers in IPM trainings in order to ensure gender equity of the program.

IPM adoption was not found to significantly influence the number of pesticide applications, as we had expected. It is understandable that we did not find a significant effect of adoption because IPM adoption in the sample was overall very low. We did, however, discover a major need in Cambodia for a reduction in the number of pesticide sprays applied to rice as 30.96% of farmers increased their use of pesticides on rice over the last 5-10 years, and the number of applications of pesticides is not statistically different between non-adopters and high adopters. As pesticide applications are high and adoption of IPM was not yet found to have a statistically significantly effect on the number of pesticide applications, IPM education in Cambodia should focus on reducing pesticide use. Additionally, the lack of adoption and high proportion of farmers who applied pesticides in Battambang despite the lack of pests indicates a significant need for IPM education in Battambang province.

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Appendix

Appendix A: Figures

A.1. Rice Pest Scientific Names and Photos

Rice caseworm

Nymphula depunctalis (Guenee), *Pyralidae*, *Lepidoptera*.

(Islam, n.d.).

Asian rice gall midge

Early Vegetative Pest

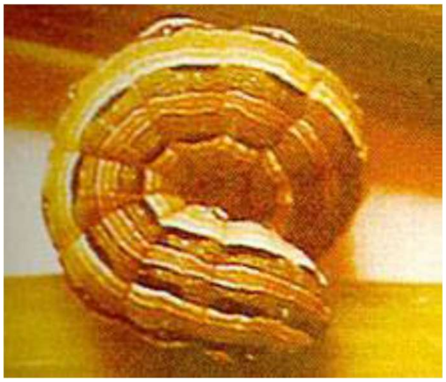
Orseolia oryzae (Wood-Mason), *Cecidomyiidae*, *Diptera*.

(Islam, n.d.).

African armyworm

General Defoliator

Spodoptera exempta (Walker), *Noctuidae*, *Lepidoptera*.

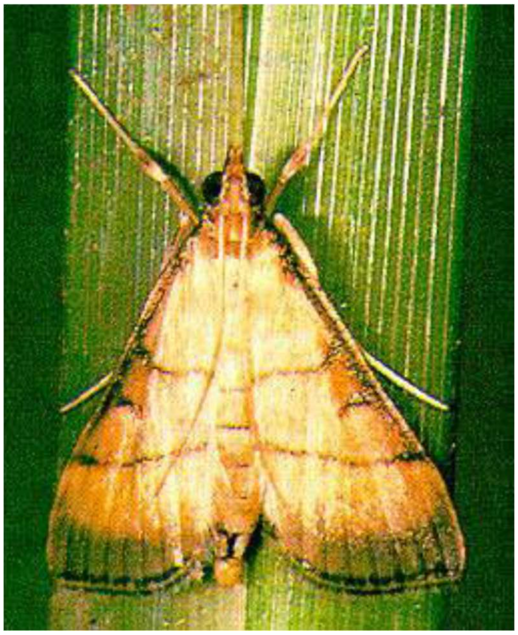


(Islam, n.d.).

Rice leaffolders

General Defoliator

Cnaphalocrocis medinalis (Guenee), *Pyralidae*, *Lepidoptera*.



(Islam, n.d.).

Golden-fringed stem borer

Stem borer

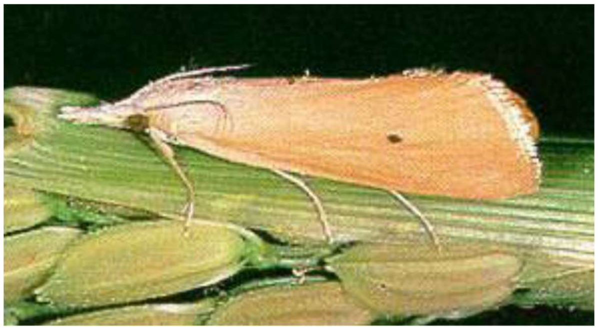
*Chilo auricilius (*Dudgeon*)*, *Pyralidae*, *Lepidoptera*.

(No image)

(Islam, n.d.).

Yellow stem borer

Scirpophaga incertulas (Walker), *Pyralidae*, *Lepidoptera*.



(Islam, n.d.).

Brown planthopper

Plant sucking pest

Nilaparvata lugens (Stal), *Delphacidae*, *Hemiptera*.

(Islam, n.d.).

Rice mealybug

Plant sucking pest

Brevennia rehi (Lindinger) *Pseudococcidae*, *Hemiptera*.

(Islam, n.d.).

Appendix B: Household Survey

IPM Innovation Lab Cambodia Interview Questionnaire

2016

ALL INFORMATION CONTAINED IN THIS
QUESTIONNAIRE IS STRICTLY

CONFIDENTIAL

SECTION 1: METADATA

INTERVIEWER: FILL IN THE ID INFORMATION BEFORE ARRIVING AT THE HOUSE, COMPLETE QUESTIONS 1 and 2 AS THE INTERVIEW BEGINS, AND COMPLETE QUESTIONS 3 and 4 AFTER THE INTERVEW

	NAME	CODE
INTID: ENUMERATOR ID		[__|__|__]
PROVINCE: NAME AND CODE OF PROVINCE		[__|__|__]
DISTRICT: NAME AND CODE OF DISTRICT		[__|__|__]
COMMUNE: NAME AND CODE OF COMMUNE		[__|__|__]
VILLAGE: NAME AND CODE OF VILLAGE		[__|__|__]
HHID: NAME AND CODE OF HOUSEHOLD		[__|__|__]

1. INTERVIEW DATE AND TIME	[__|__][__|__] 2016 **DAY/MONTH/YEAR**
2. TIME INTERVIEW STARTED	[__|__][__|__] **HH MM**
3. TIME INTERVIEW FINISHED	**[__|__][__|__]**
	HH MM
4. RESULT (SEE LIST BELOW)	**[__]**
RESULT 1 = COMPLETE 2 = NOT COMPLETE (RETURN TO HOUSEHOLD) 3 = NOT AVAILABLE 4 = REJECTION 5 = COULD NOT LOCATE HOUSEHOLD 6 = DID NOT GROW RICE 99 = OTHER (SPECIFY)______________________________	
QUALITY CONTROL	
5. DATE, INTERVIEW SUPERVISOR	[__|__][__|__] [__|__|__|__]
	DAY MONTH YEAR
6. RESULT, SUPERVISOR (CIRCLE ANSWER)	1 = COMPLETE 2 = NOT COMPLETE (RETURN TO HOUSEHOLD) 3 = NOT AVAILABLE 4 = REJECTION 5 = COULD NOT LOCATE HOUSEHOLD 6 = DID NOT GROW RICE 99 = OTHER (SPECIFY)

SECTION 2: LOCATING HOUSEHOLD AND OBTAINING CONSENT

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: YOUR FIRST JOB IS TO LOCATE THE HOUSEHOLD AND FARMER THAT WAS IDENTIFIED IN THE LIST TO BE INTERVIEWED. YOUR SECOND JOB IS TO ASCERTAIN WHO THE PRIMARY PERSON IS IN THE HOUSHOLD WHO MAKES DECISIONS WITH RESPECT TO RICE PRODUCTION. THAT IS THE PERSON WHO SHOULD BE INTERVIEWED. YOUR THIRD TASK IS TO OBTAIN CONSENT FOR THE INTERVIEW. IF YOU CANNOT FIND THE HOUSEHOLD OR THE FARMER IS NO LONGER IN THE VILLAGE, NOTE THE REASON WHY. THESE QUESTIONS WILL HELP TO DETERMINE WITH WHOM T (OR IF) THE INTERVIEW WILL BE CONDUCTED.			
1	**WERE YOU ABLE TO LOCATE THE FARMER?**	No…………………..………………………………………0 Yes……………………..………………………………..1	**->Q7** **>Q2**
2	Please write down the correct **latitude of the house.**	**[USE GPS DEVICE]: ________________________**	
3	Please write down the correct **longitude of the house.**	**[USE GPS DEVICE]: ________________________**	
4	Who makes the primary decisions with respect to rice production on your farm? (**Ask to interview the primary decision maker**)	Mostly Myself ……….……………….……………..1 Mostly My Spouse…………………………………….2 Myself and My Spouse Equally….…………….………3 Other (Specify)_________________________....99 No one…………………………………………………5	 **>STOP**
INTERVIEWER: READ THE FOLLOWING STATEMENT TO THE FARMER: "WE ARE CONDUCTING A SURVEY OF RICE PEST PROBLEMS AND PEST MANAGEMENT PRACTICES IN YOUR VILLAGE AS PART OF A PROJECT AIMED AT REDUCING RICE PEST PROBLEMS. RESPONDING TO QUESTIONS ON THIS SURVEY IS VOLUNTARY. IF YOU AGREE TO RESPOND, YOUR ANSWERS WILL REMAIN ANONYMOUS. DO YOU CONSENT TO RESPOND?"			
5	**DOES THE FARMER (HE/SHE) CONSENT TO BEING INTERVIEWED?**	No, rejects interview……..…………………………………0 Yes, accepts interview………..……………………………1 **(THANK THE FARMER FOR AGREEING TO PARTICIPATE)**	**-> STOP** **>Q6**
6	**NAME OF THE FARMER BEING INTERVIEWED**	**(WRITE DOWN NAME):_____________________**	**>SEC3**
7	**IF YOU CANNOT LOCATE THE FARMER, WHY?**	Temporarily gone for the day/week/month.……………...1 Left village (migrated)……………………………..…… 2 Community leaders never heard of the farmer…..……..3 Other (specify)___________________……………….. 99	

SECTION 3: DEMOGRAPHIC INFORMATION

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: I WOULD FIRST LIKE TO ASK YOU QUESTIONS ABOUT YOURSELF AND YOUR FAMILY.			
1	Do you have a phone?	No……………………………………………0 Yes ………………………………………………1	**->Q3** **>Q2**
2	What is your phone number?	Phone number:____________________	
3	Male or female? **[MAY NOT NEED TO ASK]**	Male……………………………………………1 Female…………………………………………2	
4	What is your age?	[___|___] Years	
5	What is your marital status?	Married (legal or not) ……………………………1 Single or never married……………………………2 Widow/widower………………………………………3 Separated/Divorced…………………………………4 Other……………………………………………………99	**>Q6** **->Q7** **->Q7** **->Q7** **->Q7**
6	What is your spouse's age?	[___|___] Years	
7	What is your primary occupation?	Agriculture (any type)……………………………1 Business………………………………………………2 Wage Job………………………………………………3 Other (specify).____________________..99	
8	What is your secondary occupation? **[NOTE SECONDARY OCCUPATION CANNOT BE SAME AS PRIMARY]**	Agriculture……………………………………………1 Business………………………………………………2 Wage Job………………………………………………3 Other (specify).____________________...99 No secondary occupation…………………………4	
9	Has the farmer ever attended school?	No…………………………………………………0 Yes…………………………………………………1	**->Q11** **>Q10**
10	How many total years of schooling have you completed (number of years)?	[___|___]	
11	Can you read in Khmer?	No…………………………………………………0 Yes…………………………………………………1	
12	Can you write in Khmer?	No…………………………………………………0 Yes…………………………………………………1	
13	How many years of experience do you have in rice cultivation?	[___|___] Years	

No	QUESTIONS	CODES/RESPONSES	GO TO
	How many family members live in your house (live under same roof)?		
14	….Number of male members?	[___|___]	
15	…Number of female members?	[___|___]	
16	How many of these family members work or are able to work? **(Q16 CANNOT BE GREATER THAN Q14 AND Q15)**	[___|___]	
17	Has the farmer's spouse ever attended school? (**IF MARRIED**)	No…………………..……………………………………0 Yes…………………..……………………………………..1	**->Q19** **>Q18**
18	How many years of schooling has the farmer's spouse completed?	[___|___] Years (1-12)	
19	Can the farmer's spouse read?	No………………..………………………………………0 Yes…………………..……………………………………..1 Does not know....……..………………………………88	
20	Can the farmer's spouse write?	No………………..………………………………………0 Yes…………………..……………………………………..1 Does not know....……..………………………………88	
21	Over the past year, how many months could you feed your family with only your household income and agricultural production?	[___|___] Months (0-12)	
22	How far is your farm from the nearest output market?	[___|___] Kilometers	
23	How far is your house from the nearest agricultural extension office?	[___|___] Kilometers	
24	How far is your house from the nearest agricultural input (seed, pesticide) dealer/store?	[___|___] Kilometers	
25	How far is your village from the district town/city?	[___|___] Kilometers	
26	Did need to borrow to finance your rice production last year?	No………………..………………………………………0 Yes…………………..……………………………………..1	**->SEC 4** **>Q27**

No	QUESTIONS	CODES/RESPONSES	GO TO
27	Was your household able to borrow the amount it needed?	No………………..……………………………………0 Yes…………………..…………………………………..1	

SECTION 4: HOUSEHOLD ASSETS

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR HOUSE			
1	What is the primary material for the walls of your house?	Simple Clay ……………..………………………………………1 Bamboo/Straw……………..…………………………………..2 Bricks/Stone………………..…………………………………..3 Wood/Iron Sheet…………………………………………………4 Other (specify)_________________________________........99	
2	What is the primary material for the roof of your house?	Straw/palm tree leaves……………………..…………….………1 Iron Sheet………..……………………………………….………..2 Brick/Concrete………………..………………………………..3 Other (specify)____________________________________…99	
3	What is the primary material for the floor of your house?	Earth…………………………………..……………………..………1 Cement…………..………………………………………..………..2 Tile……………..……………….…………………………………..3 Wood……………………………………………………………….4 Other (specify)____________________________________…99	
4	Do you have electricity in your home?	No……………………..………………………………………….…0 Yes…………………………..…………………………………..1	
5	How many rooms does your house have? [**NUMBER MUST BE GREATER THAN 0]**	[___|___] Number of rooms	
6	Do you rent or own the house you live in?	Rent……………..…………………………………….……………1 Own….………………..…..………………………….………….2 Live in house owned by relatives………………………………..3 Other (specify)....……..………………..……………………99	
7	How much land (in hectares) do you own? (**CHANGE UNITS IF NECESSARY and NOTE UNITS PER HECTARE**)	[___|___].[___|___] **IF NONE WRITE 0**	
8	How many livestock do you own?	a. Cattle (Number)……………………………… [___|___] b. Oxen (Number)….…………………………… [___|___] c. Goats/Sheep (Number)……………………… [___|___]	

SECTION 5: LAND

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT THE LAND YOU ARE FARMING.			
	How much of the land (in hectares or other units) that you and your household members currently **FARM...**		
1	…..is owned by the household?	[___|___].[___|___] **IF NONE WRITE 0**	
2	…. is rented in?	[___|___].[___|___] **IF NONE WRITE 0**	
3	…is rented out?	[___|___].[___|___] **IF NONE WRITE 0**	
4	…is sharecropped?	[___|___].[___|___] **IF NONE WRITE 0**	
5	….is farmed by other means?	[___|___].[___|___] **IF NONE WRITE 0**	
99	Specify the type of other means	____	

SECTION 6: ORGANIZATION OR GROUP MEMBERSHIP

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT THE ORGANIZATIONS AND GROUPS YOU BELONG TO.			
1	Are you or your spouse a member of any farm or community organization?	Self a member…………..………………………………………1 Spouse a member…………..……………………………..…...2 Neither a member…………………………………………..…..3	**->Section7**
2	Are you or your spouse a member of savings group?	Self a member…………..………………………………………1 Spouse a member…………..……………………………..…...2 Neither a member…………………………………………..…..3	
3	Are you or your spouse a member of a marketing cooperative or marketing group?	Self a member…………..………………………………………1 Spouse a member…………..……………………………..…...2 Neither a member…………………………………………..…..3	
99	Other group? (specify)	Specify the type of other:____	

SECTION 7: AGRICULTURAL KNOWLEDGE SOURCES

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT THE HOW YOU RECEIVE ADVICE OR LEARN ABOUT AGRICULTURE			
	In the past 12 months, have you received advice and/or learned about agriculture from……**[READ LIST]**		
1	…….an Agricultural extension worker?	No……………………………………………………0 Yes……………………………………………………1	
2	…….Relatives?	No……………………………………………………0 Yes……………………………………………………1	
3	…….Neighbor or friend?	No……………………………………………………0 Yes……………………………………………………1	
4	…….Farmer leader?	No……………………………………………………0 Yes……………………………………………………1	
5	…….Field day?	No……………………………………………………0 Yes……………………………………………………1	
6	…….Farmer field school?	No……………………………………………………0 Yes……………………………………………………1	
7	…….Seed/pesticide/ fertilizer salesperson?	No……………………………………………………0 Yes……………………………………………………1	
8	…….Radio?	No……………………………………………………0 Yes……………………………………………………1	
9	…….Television?	No……………………………………………………0 Yes……………………………………………………1	
10	…..Newspaper/Leaflet?	No……………………………………………………0 Yes……………………………………………………1	
11	…….Mobile phone message?	No……………………………………………………0 Yes……………………………………………………1	
12	…….Farmers' group?	No……………………………………………………0 Yes……………………………………………………1	
13	…….Other means not previously mentioned?	No……………………………………………………0 Yes……………………………………………………1	
14	Specify the other means	____99	

SECTION 8: RICE PRODUCTION and USE

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT THE RICE YOU PRODUCED			
1	During the 12 months, how many hectares of rice did you plant in the wet season? **[IF DID NOT GROW, WRITE 0]**	[___|___].[___|___]	
2	During the past 12 months, how many hectares of rice did you plant in the dry season? **[IF DID NOT GROW, WRITE 0]**	[___|___].[___|___]	
3	During the past 12 months, how many bags of fresh paddy rice did you sell? **[IF DID NOT GROW, WRITE 0]**	3a [___|___]___|___] Number of Bags 3b [___|___]___|___] Kilos/Bag	
4	During the past 12 months, how many bags of dry rice did you sell? **[IF DID NOT GROW, WRITE 0]**	4a [___|___]___|___] Number of Bags 4b [___|___]___|___] Kilos/Bag	
5	During the past 12 months, what was the **total value** of the rice you sold? **[IF DID NOT SELL, WRITE 0]**	[___|___]___|___]___|___] (KHR)	
6	What proportion of your rice production did you consume in your household?	None……………………………………………1 Some, but less than half………………………2 Half or more… ………………………………3	
7	If you sold rice, to whom did you sell it (**circle all that apply**) ,	Local trader………………………………1 Non-local trader…………………………..2 Cooperative……………………………….3 Sold it myself (or family did) in Market…....4 Neighbors………………………………….5 Other (Specify)…………………………..99	
8	What proportion of your family's total income is from selling rice?	None……………………………………………1 Some, but one fourth or less………………2 More than one fourth but less than half….3 One half or more…………………………4	
9	How do you water your rice production?	Irrigation system…………………………….1 Rainfed……………………………………..2 Some parcels irrigated, some rainfed.……3	

No	QUESTIONS	CODES/RESPONSES	GO TO
10	What is your source of rice seeds?	Private seed seller…………………………..1 Government seed source…………………..2 Self (saved from previous crop)……………3 Neighbor/relative/friend……………………..4 Others (specify______________________)	
11	How is rice planted in your field in the wet season?	Direct seeding………………………………1 Transplanted…………………………………2	
12	How is rice planted in your field in the dry season?	Direct seeding………………………………1 Transplanted…………………………………2	
13	What cropping pattern do you follow?	Rice-fallow……………………………………1 Rice-Rice……………………………………..2 Rice-Vegetables……………………..……3 Rice-Other……………………………………4	

SECTION 9: PESTS and PEST MANAGEMENT OF RICE

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR RICE PESTS AND PEST MANAGEMENT LAST YEAR.			
1	Which rice pest caused the **most** damage to your rice crop last year (**circle one**)?	Insects…………………………..……………………1 Diseases……………………………………………..2 Weeds…………………………………………………3 Rodents………………………………………………..4 Snails…………………………………………………..5 Birds……………………………………………………6	
2	What are the major pests that affect your dry season rice? (**SHOW PICTURES and CIRCLE ALL THAT APPPLY**)	Stemborer ………………….…………………..1 Brown plant hopper…………………………………2 Rice leaf folder………………………………………3 Brown Leaf spot……………………………………..4 Bacterial Leaf blight……………………..............5 Rice blast………..………..…………………………6 Bacterial sheath rot…………………………………7 Other, specify ________________……………99	

No	QUESTIONS	CODES/RESPONSES	GO TO
3	What are the major insect and disease pests that affect your wet season rice? (**SHOW PICTURES and CIRCLE ALL THAT APPPLY**)	Stemborer ……………….……………………..1 Brown plant hopper………………………………2 Rice leaf folder……………………………………3 Caseworm…………………………………………4 Gall midge…………………………………………5 Brown Leaf spot……………………………………6 Bacterial Leaf blight……………………...............7 Rice blast………..………..…………………………8 Bacterial sheath rot………………………………9 Other, specify _________________……………99	
4	How severe were your rice insect pests last year?	None ………………………………………….……0 Low (some damage, yield not affected)….………..1 Medium (some damage, yield affected)….……..…2 High (major damage and effect on yield).…………3	
5	What was your worst rice insect pest last year?	Specify:_________________________	
6	How severe were your rice disease pests last year?	None ………………………………………….……0 Low (some damage, yield not affected)….………..1 Medium (some damage, yield affected)….……..…2 High (major damage and effect on yield).…………3	
7	What was your **worst** rice disease last year?	Specify:_________________________	
8	How many times did you apply insecticides to your rice during the last rice season?	[___|___] Total Number of Applications	
9	How many times did you apply fungicides to your rice during the last rice season?	[___|___] Total Number of Applications	
10	How many times did you apply herbicides to your rice during the last rice season?	[___|___] Total Number of Applications	
11	How many times did you apply rodenticides to your rice during the last rice season?	[___|___] Total Number of Applications	
12	How much did you spend on pesticides during the last rice season?	[___|___].[___|___] (KHR)	
13	Did you or someone in your family apply the pesticides?	No……………………..…………………………0 Yes…………………………..……………………...1	**>Q16** **>Q14**

No	**QUESTIONS**	**CODES/RESPONSES**	**GO TO**
14	If yes, how many people in your family applied the pesticides?	[___|___] Number of people	
15	How many days, on average, did each person spend applying pesticides?	[___|___] Number of days	
16	Did you pay for labor to apply pesticides, and if so, how much?	[___|___]___|___]___|___] (KHR)	
17	Have you or anyone in your family ever become ill from applying pesticides?	No……………………….…………………………0 Yes…………………………..……………………...1	
18	If you became ill applying pesticides, what were your symptoms? (**CIRCLE ALL THAT APPLY**)	Dizziness, difficulty walking, or numbness…………1 Headache or blurred vision…………………………..2 Nausea or vomiting……………………………………3 Chest or stomach pain………………………………..4 Skin rash………………………………………………5 Convulsions……………………………………………6 Other: (Specify)______________________..........7	
19	How many people manually weeded your rice last season?	[___|___] Number of people	
20	How many days per person were spent manually weeding your rice last season?	[___|___] Number of days	
21	Who does your manual weeding of rice? **(CIRCLE ALL THAT APPLY)**	Mostly Myself ……………….………………..1 Mostly My Spouse…………………………….2 Myself and My Spouse Equally…….….……3 Others…………………………………………4 No One………………..……………………5	

No	QUESTIONS	CODES/RESPONSES	GO TO
22	Which of the following non-pesticide or minimal-pesticide practices, if any, did you use to control rice insect, disease, weed, or rodent pests? **(CIRCLE ALL THAT APPLY)**	Pest-resistant variety……………………..…………1 Stale seedbed (sequential harrowing or harrowing followed by a non-selective herbicide) ..…………2 Apply Trichoderma on seeds or seedlings……....3 No insecticide spray for the first 40 days…………4 Apply microbial pesticide (e.g., *Metarhizium sp.* and *Beauveria sp.*)…………………………..……..5 Apply bio-pesticide such as neem........................6 *Sarcocystis* bait for rodents………………………..7 Hand weeding at recommended growth stage…..8 Other (Specify)___________________……… None…………………………………………………0	->Sec10
23	Why did you use a non-pesticide or minimal-pesticide practice(s)? **(CIRCLE ALL THAT APPLY)**	Cost less than pesticides…………………………....1 More effective than pesticides……………..……...2 Safer for my own or my family's health………..….3 Better for the environment (water, soil, birds, etc.)..4 Protects beneficial insects …………………………..5 Market prefers or requires it…………………………6	

SECTION 10: IPM TRAINING

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT THE TYPE OF TRAINING YOU HAVE RECEIVED ON INTEGRATED PEST MANAGEMENT (IPM) AND PESTICIDE USE			
1	Have you received any training related to IPM?	No………..…………………………..…………0 Yes……………..………………………………..1	->SEC11 >Q2
2	If yes, how many times have you received IPM training?	[___|___] Number	
3	From whom did you receive training? **[READ LIST BELOW]**		
a	……DAE (Department of Agricultural Extension)	No………..……………………..…………………0 Yes……………..………………………………..1	
b	……PDA (Provincial Department of Agriculture)		

No	QUESTIONS	CODES/RESPONSES	GO TO
c	……GDA (General Directorate of Agriculture)	No……………………………………………0 Yes……………………………………………1	
d	……NGO (ex. CARE, iDE, CODES, etc.)	No……………………………………………0 Yes……………………………………………1	
e	……Private companies		
f	……Other	No……………………………………………0 Yes……………………………………………1	->SEC11
g	Specify the other	______________________________99	
4	Who in your family normally attends any training that is given on IPM?	Mostly Myself ……………………………………1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally………………………3 Other (Specify)____________________....99 No one…………………………………………………5	

SECTION 11: GENDER and IPM

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER: SAY TO THE FARMER: NOW I WOULD LIKE TO ASK YOU A FEW QUESTIONS ABOUT PEST MANAGEMENT DECISION MAKING ON YOUR FARM			
1	Who buys pesticides or other pest management products?	Mostly Myself ……………………………………1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally………………………3 Other (Specify)____________________....99 No one…………………………………………………5	
2	Who decides how much to spend on pesticides or other pest management products?	Mostly Myself ……………………………………1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally………………………3 Other (Specify)____________________....99 No one…………………………………………………5	
3	Who mixes the pesticides before they are applied to rice?	Mostly Myself ……………………………………1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally………………………3 Other (Specify)____________________....99 No one…………………………………………………5	
3	Who applies pesticides or other pest management products when needed?	Mostly Myself ……………………………………1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally………………………3 Other (Specify)____________________....99 No one…………………………………………………5	

No	QUESTIONS	CODES/RESPONSES	GO TO
4	When pest problems occur, who in your family decides what to do?	Mostly Myself ……………………………………..1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally……………………3 Other (Specify)_________________________....99 No one…………………………………………………5	
5	When money is earned from selling rice, who in your family decides how it is spent?	Mostly Myself ……………………………………..1 Mostly My Spouse……………………………………2 Myself and My Spouse Equally……………………3 Other (Specify)_________________________....99 No one…………………………………………………5	

SECTION 12: PESTICIDE USE, SAFETY, KNOWLEDGE, AND EDUCATION

No	QUESTIONS	CODES/RESPONSES	GO TO
INTERVIEWER SAYS TO THE FARMER: NOW I WOULD LIKE TO ASK YOU A FEW MORE QUESTIONS RELATED TO YOUR USE OF PESTICIDES ON RICE			
1	Has your use of pesticides on rice increased or decreased over the last 5-10 years?	Increased………………………………………………1 Decreased……………………………………………..2 Stayed the same……………………………………3 Do not use pesticides………………………………4	**>Q2** **>Q2** **>Q3** **>Q23**
2	Why did your pesticide use change?	More pests……………………………………………..1 Greater pest damage to crop………………………..2 Advice from pesticide dealer………………………..3 Can now afford to use more…………………………4 Other (Specify)__________________________..99	
3	How many weeks after planting did you first apply pesticides to your rice?	[___|___] Number of weeks	
4	How effective were the insecticides you applied on rice during the past year?	Effective………………………………………………1 Not effective…………………………………………..2 Don't know……………………………………………3 Did not apply any insecticides………………………4	
5	How effective were the fungicides you applied on rice during the past year?	Effective………………………………………………1 Not effective…………………………………………..2 Don't know……………………………………………3 Did not apply any fungicides..………………………4	
6	How effective were the herbicides you applied on rice during the past year?	Effective………………………………………………1 Not effective…………………………………………..2 Don't know……………………………………………3 Did not apply any herbicides..………………………4	

No	QUESTIONS	CODES/RESPONSES	GO TO
7	How effective were the rodenticides you applied on rice during the past year?	Effective……………………………………………1 Not effective…………………………………….2 Don't know……………………………………3 Did not apply any rodenticides..……………………4	
8	Where do you obtain your pesticides? **(CIRCLE ALL THAT APPLY)**	Local pesticide dealer………………………………1 Local store……………………………………….2 Government…………………………………….3 Neighbor……………………………………………4 Other (Specify)____________________________99	
9	Do you mix differ types of pesticides together when applying them to rice?	No……………………………………………………1 Yes………………………………………………….2	
10	What pesticides do you apply to rice?	methyl parathion……………………………….…..1 mevinphos……………………………………….2 methamidophos…………………………………3 2,4-D…………………………………………………4 Dichlorvos………………………………….……5 Monocrotophos…………………………….……6 Cypermethrin………………………………………7 Other (Specify)_________________________...99	
11	What factors influence your choice of pesticides? **(CIRCLE ALL THAT APPLY)**	Cost………………………………………………….……1 Effectiveness against the pest……………………….2 Pesticide dealers……………………………………3 Extension agents……………………………………4 Advertising…………………………………………..5 Other (Specify)______________________.........99	
12	How do you decide on the pesticide **dosage** to apply? **(CIRCLE ALL THAT APPLY)**	Read label on pesticide container…………….……..1 Advice from pesticide dealer…………………………2 Advice from extension agent…………………………3 Advice from relative or neighbor……………………..4 Other (Specify)_________________________.....99	
13	How do you decide **when** to apply pesticides? **(CIRCLE ALL THAT APPLY)**	Read label on pesticide container…………….……..1 Advice from pesticide dealer…………………………2 Advice from extension agent…………………………3 Advice from relative or neighbor……………………..4 Growth stage of plant…………………………………5 Spray at regular or fixed intervals…………………..6 Based on number of pests……………………………7 Based on visible damage……………………………8 Other (Specify)_________________________.....99	

No	QUESTIONS	CODES/RESPONSES	GO TO
14	Where do you store your pesticides?	In my house……………………………………………..1 Just outside my house………………………………2 In a building or location separate from my house..3 Other (Specify)______________________...........99	
15	How do you dispose of your empty pesticide containers? **(CIRCLE ALL THAT APPLY)**	Bury………………………………………………….1 Throw in field………………………………………..2 Throw in canal……………………………………..3 Burn…………………………………………………4 Wash and reuse container…………………………5 Other (Specify)___________________________99	
16	What type of sprayer do you use to apply pesticides?	Hand pump……………………………………………1 Tank sprayer…………………..……………………2 Other (Specify)_________________________…99 No sprayer……………………………………………..3	
17	Do you calibrate your sprayer?	No……………………………………………………1 Yes……………………………………………………2 No sprayer……………………………………….…..3	
18	Have you ever considered or used more than one type of nozzle for your sprayer?	No……………………………………………………1 Yes……………………………………………………2 No sprayer……………………………………………...3	
19	What clothes do you wear while applying pesticides? **(CIRCLE ALL THAT APPLY**)	Short sleeve top………………………………………1 Long sleeve top…………………………………….…..2 Short pants……………………………………………3 Long pants……………………………………………..4 Shoes…………………………………………………..5 Sandals…………………………………………….…..6 Rubber boots…………………………………………..7 Hat……………………………………………………8 Mask…………………………………………………9	
20	Have you ever had training in pesticide safety?	No……………………………………………………1 Yes……………………………………………………2	
21	Would you like to receive further training on pesticides?	No……………………………………….……….1 Yes……………………………………………………..2	**->Q15** **>Q14**
22	What topics would you like to learn about? (**CIRCLE ALL THAT APPLY**)	Signs and symptoms of poisoning …………………1 Minimizing risks associated with using pesticides..2 Proper pesticide application procedures (dosage, timing, which pesticide for specific pests, etc.)...……3 Alternatives to pesticides……………………………4 Other (Specify)_______________________.........99	

No	QUESTIONS	CODES/RESPONSES	GO TO
23	Are there insects that do not cause damage to your rice crop, but actually benefit it?	No……………………………………………..………..1 Yes……………………………………………………..2 Don't know…………………………………………3	**->Stop** **>Q16**
24	Do you agree that killing insects that benefit your rice field can increase rice pest infestation?	Agree………………………………………………..1 Disagree……………………………………………..2 Don't know……………………………………………3	

Thank you for your time!

Appendix C: Tables

Table C.1. Pesticide Applications by Gender of Pesticide Applicator: Bonferroni's Adjusted Significance Test

Row Mean – Column Mean	**Husband/Male Head**	**Wife/Female Head**	**Both Spouses Equally**	**No One**
Wife/Female Head	0.315 **1.00**			
Both Spouses Equally	-0.911 **1.00**	-1.225 **0.36**		
No One	-2.70 **0.00**	-3.013 **0.00**	-1.787 **0.02**	
Other (Child, Brother, Hired Labor, etc.)	-0.103 **1.00**	-0.418 **1.00**	0.808 **1.00**	2.595 **0.00**

C.2. Distribution of Land Ownership by Pesticide Applications

Pesticide Applications	Mean Land Owned (Ha)	Std Dev	Frequency
0	1.16	1.05	95
1	2.42	3.18	82
2	1.91	1.93	77
3	2.32	3.16	61
4	2.29	2.32	27
5	2.92	4.43	25
6	1.18	1.03	6
7	4.74	6.03	10
8	10	0	1
9	3.25	1.06	2
10	3.1	2.78	5
12	1.5	0	1
13	18	0	1
15	2	0	1

C.3. Sources of Agricultural Knowledge – All Responses

“In the past 2 years, have you received advice and/or learned about agriculture from any of the following sources?”

Grouping	Source	Yes	No	Total
Extension	Government agricultural extension worker/center	33.25% (131)	66.75% (263)	394
	NGO agricultural extension worker	35.79% (141)	64.21% (253)	
	Field day	1.78% (7)	98.22% (387)	
	Farmer field school	1.27% (5)	98.73% (389)	
Media	Radio	30.71% (121)	69.29% (273)	394
	Video (TV, YouTube)	26.40% (104)	73.60% (290)	
	Newspaper, Leaflet	2.03% (8)	97.97% (386)	
	Mobile phone message	1.27% (5)	98.73% (389)	
	Social media (Facebook, etc.)	1.52% (6)	98.48% (388)	
Input Suppliers	Farm input salesperson	69.80% (275)	30.20% (119)	394
Personal source	Relatives	26.65% (105)	73.35% (289)	394
	Neighbor, friend	64.72% (255)	35.28% (139)	
	Farmer leader	10.66% (42)	89.34% (352)	
	Farmers’ group	11.42% (45)	88.58% (349)	
	Other	1.02% (4)	98.98% (390)	

C.4. Top Agricultural Knowledge Sources by Adoption Level

"In the past 2 years, which of these would you consider one of your two most important sources of agricultural advice or information?"

Grouping	**Source**	**Non-Adopters**	**Low Adopters**	**High Adopters**	**Total Resp.**
Extension	Government agricultural extension worker/center	20	60	5	730
	NGO agricultural extension worker	22	66	19	
	Field day	0	0	0	
	Farmer field school	1	0	1	
Media	Radio	10	28	9	730
	Video (TV, YouTube)	7	28	6	
	Newspaper, Leaflet	0	2	0	
	Mobile phone message	1	1	0	
	Social media (Facebook, etc.)	2	1	0	
Input Suppliers	Farm input salesperson	79	86	11	730
Personal source	Relatives	18	28	6	730
	Neighbor, friend	69	97	13	
	Farmer leader	3	10	4	
	Farmers' group	0	2	1	
	Other	1	2	2	
Total Responses Given		232	411	77	730

***Note: Frequencies given.**

C.5. Change in Pesticide Usage

"Has your use of pesticides on rice increased or decreased over the last 5-10 years?"

	Non-Adopters	Low Adopters	High Adopters	Total
Increased	44.44% (56)	26.32% (60)	15.00% (6)	30.96% (122)
Decreased	1.59% (2)	3.51% (8)	5.00% (2)	3.05% (12)
Stayed the same	52.38% (66)	32.02% (73)	65.00% (26)	41.88% (165)
N/A (Do not use pesticides)	1.59% (2)	38.16% (87)	15.00% (6)	24.11% (95)
Total	100.00% (126)	100.00% (228)	100.00% (40)	100.00% (394)

C.6. Disease Severity by Use of Pesticides

Disease Severity	Did not apply pesticides in the past 12 months	Applied pesticides in the past 12 months	Total
None/Low	28.20% (86)	71.80% (219)	100.00% (305)
Medium	10.94% (7)	89.06% (57)	100.00% (64)
High	8.00% (2)	92.00% (23)	100.00% (25)
Total	24.11% (95)	75.89% (299)	100.00% (394)

C.7. Why Pesticide Use Changed

	Non-Adopters	Low Adopters	High Adopters
More pests or fewer pests	31.03% (18)	30.88% (21)	25.00% (2)
Greater or less pest damage	79.31% (46)	84.29% (58)	75.00% (6)
Advice from pesticide dealer	18.97% (11)	11.76% (8)	12.50% (1)
Can now afford to use more	5.17% (3)	1.47% (1)	0.00% (0)
Rice acreage changed	0.00% (0)	1.47% (1)	0.00% (0)
Other (Labor shortage)	3.45% (2)	0.00% (0)	0.00% (0)
Total	(58)	(68)	(8)

C.8. Adoption Level by Gender of Person Who Became Ill from Pesticide Exposure

Gender of person who became ill	**Non-Adopters**	**Low Adopters**	**High Adopters**	**Total**
No one:	21.60% (27)	52.63% (120)	41.03% (16)	41.58% (163)
Men only:	70.40% (88)	40.35% (92)	43.59% (17)	50.26% (197)
Women and children:	8.00% (10)	7.02% (16)	15.38% (6)	8.16% (32)
Total	100.00% (126)	100.00% (228)	100.00% (40)	100.00% (394)

Chi2 Pr = 0.000

C.9. Person Who Generally Applies Pesticides or Pest Management Products

Person	Mean Pesticide Applications	Std Dev	Frequency
Husband or Male Head	2.91	2.14	146
Wife or Female Head	3.22	2.49	102
Both Spouses Equally	2.00	1.20	12
Other	2.81	1.55	26
No One	0.21	0.64	108
Total:	2.22	2.27	394

C.10. Person Who Decides What to Do When Pest Problems Occur

Person	Mean Pesticide Applications	Std Dev	Frequency
Husband or Male Head	2.69	1.90	120
Wife or Female Head	3.22	2.65	73
Both Spouses Equally	3.29	2.25	80
Other	1.90	1.45	10
No One	0.31	0.83	111
Total:	2.22	2.27	394

C.11. Education Level by Gender

Education Level	Male Primary Farmer	Female Primary Farmer	Total
None	8.10% (17)	27.17% (50)	17.01% (67)
Some primary	46.19% (97)	48.37% (89)	47.21% (186)
Some secondary or higher	45.71% (96)	24.46% (45)	35.79% (141)
Total:	100.00% (210)	100.00% (184)	100.00% (394)

C.12. Province by Use of Pesticides

Province	Did not apply pesticides in the past 12 months	Applied pesticides in the past 12 months	Total
Takeo	36.36% (36)	63.64% (63)	100.00% (99)
Prey Veng	9.38% (9)	90.63% (87)	100.00% (96)
Kampong Thom	44.90% (44)	55.10% (54)	100.00% (98)
Battambang	5.94% (6)	94.06% (95)	100.00% (101)
Total	24.11% (95)	75.89% (299)	100.00% (394)

C.13. Severity of Insect Pests by Province

Province	None or Low Severity	Medium Severity	High Severity	Total
Takeo	58.59% (58)	19.19% (19)	22.22% (22)	100.00% (99)
Prey Veng	53.13% (51)	35.42% (34)	11.46% (11)	100.00% (96)
Kampong Thom	75.51% (74)	15.31% (15)	9.18% (9)	100.00% (98)
Battambang	69.31% (70)	28.71% (29)	1.98% (2)	100.00% (101
Total	64.21% (253)	24.62% (97)	11.17% (44)	100.00% (394)

Appendix D: Stata Output

D.1.1 Adoption Model Regression Results with 2 Levels for Adoption, Group of 29 Observations Dropped

```
1   . logit ADOPTADROP i.FEMALE EXP i.EDUC HSHLDLABOR DISTANCE LANDOWNED HECTARESRIC > E
    TRAININGTIMES i.FEMALE#c.TRAININGTIMES i.EXTENSION i.MEDIA i.INPUTSUPPLIERS > i.PERSONALSOURCE

    Iteration 0:   log likelihood = -126.16417
    Iteration 1:   log likelihood = -118.33365
    Iteration 2:   log likelihood = -117.55643
    Iteration 3:   log likelihood =  -117.5541
    Iteration 4:   log likelihood =  -117.5541

    Logistic regression                 Number of obs     =        365
                                   LR chi2(14)       =      17.22
                                   Prob > chi2       =     0.2446
    Log likelihood =  -117.5541                Pseudo R2         =     0.0682
    ---------------------------------------------------------------------------
      ADOPTADROP      |    Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
    ------------------+--------------------------------------------------------
                      |
        1.FEMALE      |  .2702559   .4048723    0.67   0.504    -.5232793    1.063791
           EXP        |  .0059762   .0134757    0.44   0.657    -.0204356     .032388
                      |
         EDUC         |
           1          |  .0133881   .5321293    0.03   0.980    -1.029566    1.056342
           2          |  .2536645   .5517624    0.46   0.646      -.82777    1.335099
                      |
                      | -.2785955   .1335005   -2.09   0.037    -.5402516   -.0169394
      HSHLDLABOR      |
        DISTANCE      | -.0254052   .0363573   -0.70   0.485    -.0966642    .0458538
       LANDOWNED      |  .1055251   .1245654    0.85   0.397    -.1386186    .3496688
     HECTARESRICE     | -.0585502   .0951538   -0.62   0.538    -.2450482    .1279478
    TRAININGTIMES     |   .062759   .1141918    0.55   0.583    -.1610528    .2865708
                      |
                      |
        FEMALE#       |
    c. TRAININGTIMES  |
           1          |
                      |  .0059898   .1939448    0.03   0.975     -.374135    .3861146
                      |  .7277575   .4698447    1.55   0.121    -.1931211    1.648636
      1.EXTENSION     |
        1.MEDIA       |  .8107071     .46553    1.74   0.082     -.101715    1.723129
    1.INPUTSUPP~S     | -.4416975   .4418803   -1.00   0.318    -1.307767    .4243719
    1.PERSONALS~E     |  .3799124   .4345871    0.87   0.382    -.4718627    1.231687
          _cons       | -2.092593   1.019539   -2.05   0.040    -4.090853   -.0943322
    ---------------------------------------------------------------------------
2   . margins, dydx(*)

    Average marginal effects                Number of obs     =        365 Model VCE    : OIM

    Expression   : Pr(ADOPTADROP), predict()
    dy/dx w.r.t. : 1.FEMALE EXP 1.EDUC 2.EDUC HSHLDLABOR DISTANCE LANDOWNED              HECTARESRICE
    TRAININGTIMES 1.EXTENSION 1.MEDIA 1.INPUTSUPPLIERS              1.PERSONALSOURCE
    ---------------------------------------------------------------------------
                      |             Delta-method
                      |      dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
    ------------------+--------------------------------------------------------
                      |
        1.FEMALE      |  .0257023   .0354039    0.73   0.468     -.043688    .0950926
           EXP        |  .0005528   .0012458    0.44   0.657     -.001889    .0029945
                      |
```

```
        EDUC      |
          1       |   .0011546   .045784    0.03   0.980   -.0885804   .0908896
          2       |   .0238759   .0501577   0.48   0.634   -.0744315   .1221832
                  |
                  |  -.0257684   .0124045  -2.08   0.038   -.0500807  -.0014561
     HSHLDLABOR   |
       DISTANCE   |  -.0023498   .0033656  -0.70   0.485   -.0089464   .0042467
   Tuesday October 10 17:31:37 2017   Page 2
      LANDOWNED   |   .0097604   .0115366   0.85   0.398   -.0128508   .0323717
    HECTARESRICE  |  -.0054155   .0088113  -0.61   0.539   -.0226854   .0118543
  TRAININGTIMES   |    .006069   .0092396   0.66   0.511   -.0120404   .0241784
    1.EXTENSION   |   .0714887   .0491321   1.46   0.146   -.0248084   .1677858
        1.MEDIA   |   .0881296   .0582988   1.51   0.131    -.026134   .2023932
  1.INPUTSUPP~S   |  -.0393879   .0379717  -1.04   0.300   -.1138111   .0350353
  1.PERSONALS~E   |   .0348102   .0394255   0.88   0.377   -.0424624   .1120828
---------------------------------------------------------------------------------
  Note: dy/dx for factor levels is the discrete change from the base level.

3  .
4  . margins, dydx(FEMALE) at(TRAININGTIMES=(1(1)12))

   Average marginal effects              Number of obs    =     365 Model VCE    : OIM

   Expression   : Pr(ADOPTADROP), predict() dy/dx w.r.t. : 1.FEMALE

   1._at      : TRAININGTI~S    =     1

   2._at      : TRAININGTI~S    =     2

   3._at      : TRAININGTI~S    =     3

   4._at      : TRAININGTI~S    =     4

   5._at      : TRAININGTI~S    =     5

   6._at      : TRAININGTI~S    =     6

   7._at      : TRAININGTI~S    =     7

   8._at      : TRAININGTI~S    =     8

   9._at      : TRAININGTI~S    =     9

   10._at     : TRAININGTI~S    =     10

   11._at     : TRAININGTI~S    =     11

   12._at     : TRAININGTI~S    =     12
---------------------------------------------------------------------------------
                  |        Delta-method
                  |   dy/dx   Std. Err.     z    P>|z|    [95% Conf. Interval]
---------------------------------------------------------------------------------
   0.FEMALE       |  (base outcome)
---------------------------------------------------------------------------------
   1.FEMALE       |
   _at            |
          1       |  .0260758   .0360509    0.72   0.469   -.0445827    .0967343
          2       |  .0278917   .0448494    0.62   0.534   -.0600116    .1157949
          3       |  .0297924    .060924    0.49   0.625   -.0896165    .1492012
          4       |  .0317777   .0815478    0.39   0.697   -.1280532    .1916085
          5       |   .033847   .1053853    0.32   0.748   -.1727043    .2403984
          6       |  .0359993   .1318677    0.27   0.785   -.2224567    .2944554
          7       |  .0382328   .1607392    0.24   0.812   -.2768103     .353276
```

8	.0405453	.191871	0.21	0.833	-.335515	.4166055
9	.0429336	.2251865	0.19	0.849	-.3984239	.4842912
10	.0453944	.2606291	0.17	0.862	-.4654292	.556218
11	.0479232	.2981454	0.16	0.872	-.5364311	.6322775
12	.0505151	.3376777	0.15	0.881	-.611321	.7123512

Note: dy/dx for factor levels is the discrete change from the base level.

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D.1.2 Adoption Model Regression Results with 3 Levels for Adoption, Group of 29 Observations Dropped

```
1 . mlogit ADOPTBDROP i.FEMALE EXP i.EDUC HSHLDLABOR DISTANCE LANDOWNED HECTARESRI > CE
    TRAININGTIMES i.FEMALE#c.TRAININGTIMES i.EXTENSION i.MEDIA i.INPUTSUPPLIERS >  i.PERSONALSOURCE,
    b(0)

    Iteration 0:   log likelihood = -343.16818
    Iteration 1:   log likelihood = -312.00405
    Iteration 2:   log likelihood = -310.91741
    Iteration 3:   log likelihood = -310.91311
    Iteration 4:   log likelihood = -310.91311

    Multinomial logistic regression              Number of obs    =       365
                                        LR chi2(28)      =      64.51
                                        Prob > chi2      =     0.0001
    Log likelihood = -310.91311                  Pseudo R2        =     0.0940
    ------------------------------------------------------------------------------------------
       ADOPTBDROP     |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
    ------------------+---------------------------------------------------------------------
    0                 |   (base outcome)
                      |
    ------------------+---------------------------------------------------------------------
    1                 |
         1.FEMALE     |   .3980237   .2775672     1.43   0.152    -.1459981    .9420455
             EXP      |   .0304392   .0104503     2.91   0.004      .009957    .0509215
                      |
            EDUC      |
              1       |   .1084545   .3576051     0.30   0.762    -.5924386    .8093475
              2       |  -.3099871    .383654    -0.81   0.419    -1.061935     .441961
                      |  -.1642572   .0827853    -1.98   0.047    -.3265135   -.0020009
       HSHLDLABOR     |
         DISTANCE     |  -.0336543    .023869    -1.41   0.159    -.0804366     .013128
        LANDOWNED     |  -.0689671   .0772998    -0.89   0.372     -.220472    .0825378
      HECTARESRICE    |  -.0018137   .0458187    -0.04   0.968    -.0916167    .0879893
    TRAININGTIMES     |  -.0667453   .0990567    -0.67   0.500    -.2608929    .1274022
                      |
    FEMALE#        c. |
    TRAININGTIMES     |
              1       |
                      |  -.0768899   .1645212    -0.47   0.640    -.3993454    .2455657
                      |   .9822242   .3661343     2.68   0.007     .2646142    1.699834
      1.EXTENSION     |
         1.MEDIA      |   .5823518   .3881954     1.50   0.134    -.1784972    1.343201
    1.INPUTSUPP~S     |   -.647347    .280959    -2.30   0.021    -1.198017   -.0966775
    1.PERSONALS~E     |    .208393   .3181438     0.66   0.512    -.4151574    .8319434
           _cons      |   .2383189    .702373     0.34   0.734    -1.138307    1.614945
    ------------------+---------------------------------------------------------------------
    2                 |
         1.FEMALE     |   .5559138   .4477309     1.24   0.214    -.3216227     1.43345
             EXP      |   .0270232   .0155228     1.74   0.082    -.0034009    .0574472
                      |
            EDUC      |
              1       |   .0801875   .5890508     0.14   0.892    -1.074331    1.234706
              2       |   .0346758   .6119463     0.06   0.955    -1.164717    1.234069
                      |  -.3978837   .1463739    -2.72   0.007    -.6847712   -.1109962
       HSHLDLABOR     |
         DISTANCE     |  -.0472402   .0396947    -1.19   0.234    -.1250403    .0305599
        LANDOWNED     |   .0684721   .1307433     0.52   0.600      -.18778    .3247243
```

```
 HECTARESRICE    | -.0563876  .0965471   -0.58  0.559   -.2456166   .1328413
TRAININGTIMES    |  .0210692  .1301231    0.16  0.871   -.2339673   .2761057
                 |
                 |
      FEMALE#    |
c. TRAININGTIMES |
          1      |
                 | -.0416733  .2209563   -0.19  0.850   -.4747397   .3913931
                 |  1.401671  .5423083    2.58  0.010    .3387658   2.464575
  1.EXTENSION    |
      1.MEDIA    |  1.223092  .5472819    2.23  0.025    .1504391   2.295745
1.INPUTSUPP~S    | -.8434336  .4742016   -1.78  0.075   -1.772852   .0859844
1.PERSONALS~E    |   .540971  .4914938    1.10  0.271   -.4223391   1.504281
        _cons    | -1.290057  1.128212   -1.14  0.253   -3.501312   .9211986
-------------------------------------------------------------------------------
2   . margins, dydx(*)

Average marginal effects                Number of obs     =       365 Model VCE    : OIM

dy/dx w.r.t. : 1.FEMALE EXP 1.EDUC 2.EDUC HSHLDLABOR DISTANCE LANDOWNED              HECTARESRICE
TRAININGTIMES 1.EXTENSION 1.MEDIA 1.INPUTSUPPLIERS
              1.PERSONALSOURCE
1._predict   : Pr(ADOPTBDROP==0), predict(pr outcome(0)) 2._predict   : Pr(ADOPTBDROP==1),
predict(pr outcome(1))
3._predict   : Pr(ADOPTBDROP==2), predict(pr outcome(2))

-------------------------------------------------------------------------------
                 |     Delta-method
                 |   dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------------------------------------------------------------------
0.FEMALE         |  (base outcome)
-------------------------------------------------------------------------------
1.FEMALE         |
_predict         |
          1      | -.0733042  .0491441   -1.49  0.136   -.1696249   .0230166
          2      |  .0460941  .0538869    0.86  0.392   -.0595223   .1517104
          3      |  .0272101  .0355259    0.77  0.444   -.0424194   .0968396
-------------------------------------------------------------------------------
                 |
EXP      _predict|
          1      | -.0058003  .0018961   -3.06  0.002   -.0095167   -.002084
          2      |   .005227  .0020241    2.58  0.010    .0012597   .0091942
          3      |  .0005733   .001236    0.46  0.643   -.0018492   .0029959
-------------------------------------------------------------------------------
0.EDUC           |  (base outcome)
-------------------------------------------------------------------------------
1.EDUC           |
_predict         |
          1      | -.0198465  .0669605   -0.30  0.767   -.1510867   .1113938
          2      |  .0195661  .0729523    0.27  0.789   -.1234178   .1625501
          3      |  .0002804  .0459134    0.01  0.995   -.0897083    .090269
-------------------------------------------------------------------------------
2.EDUC           |
_predict         |
          1      |  .0505697  .0732186    0.69  0.490   -.0929362   .1940755
          2      | -.0734422   .078915   -0.93  0.352   -.2281128   .0812283
          3      |  .0228726  .0502171    0.46  0.649   -.0755511   .1212962
-------------------------------------------------------------------------------
HSHLDLABOR       |
_predict         |
          1      |  .0386644  .0152911    2.53  0.011    .0086944   .0686343
          2      | -.0122534  .0172387   -0.71  0.477   -.0460405   .0215338
          3      |  -.026411    .01249   -2.11  0.034   -.0508909   -.001931
-------------------------------------------------------------------------------
```

DISTANCE						
_predict						
1	.0069202	.0044633	1.55	0.121	-.0018277	.0156682
2	-.0046802	.004983	-0.94	0.348	-.0144466	.0050863
3	-.0022401	.0033678	-0.67	0.506	-.0088409	.0043608
LANDOWNED						
_predict						
1	.0093525	.0142037	0.66	0.510	-.0184862	.0371911
2	-.0200514	.0171443	-1.17	0.242	-.0536537	.0135509
3	.0106989	.0117143	0.91	0.361	-.0122607	.0336585
HECTARESRICE						
_predict						
1	.0019461	.0086172	0.23	0.821	-.0149434	.0188355
2	.0031553	.010842	0.29	0.771	-.0180946	.0244052
3	-.0051014	.0087544	-0.58	0.560	-.0222597	.0120569
TRAININGTIMES						
_predict						
1	.0165605	.0155129	1.07	0.286	-.0138443	.0469652
2	-.0233227	.0172618	-1.35	0.177	-.0571552	.0105098
3	.0067622	.0095007	0.71	0.477	-.0118588	.0253833
0.EXTENSION	(base outcome)					
1.EXTENSION						
_predict						
1	-.1987496	.0625526	-3.18	0.001	-.3213505	-.0761487
2	.1279525	.0709769	1.80	0.071	-.0111598	.2670647
3	.0707971	.0491477	1.44	0.150	-.0255305	.1671248
0.MEDIA	(base outcome)					
1.MEDIA						
_predict						
1	-.1280964	.0646642	-1.98	0.048	-.254836	-.0013568
2	.0392343	.0758406	0.52	0.605	-.1094105	.1878792
3	.088862	.058868	1.51	0.131	-.0265171	.2042412
0.INPUTSUPP~S	(base outcome)					
1.INPUTSUPP~S						
_predict						
1	.1373415	.0565886	2.43	0.015	.02643	.2482531
2	-.0996542	.0602532	-1.65	0.098	-.2177483	.0184399
3	-.0376873	.0384806	-0.98	0.327	-.1131078	.0377332
0.PERSONALS~E	(base outcome)					
1.PERSONALS~E						
_predict						
1	-.0496017	.0593852	-0.84	0.404	-.1659945	.0667912
2	.0132507	.0637577	0.21	0.835	-.1117121	.1382136
3	.036351	.0393773	0.92	0.356	-.0408271	.113529

Note: dy/dx for factor levels is the discrete change from the base level.

3 .

```
4  . margins, dydx(FEMALE) at(TRAININGTIMES=(1(1)12))

   Average marginal effects              Number of obs    =     365 Model VCE   : OIM

   dy/dx w.r.t. : 1.FEMALE
   1._predict   : Pr(ADOPTBDROP==0), predict(pr outcome(0)) 2._predict   : Pr(ADOPTBDROP==1),
   predict(pr outcome(1))
   3._predict   : Pr(ADOPTBDROP==2), predict(pr outcome(2))

   1._at      : TRAININGTI~S   =       1

   2._at      : TRAININGTI~S   =       2

   3._at      : TRAININGTI~S   =       3

   4._at      : TRAININGTI~S   =       4

   5._at      : TRAININGTI~S   =       5

   6._at      : TRAININGTI~S   =       6

   7._at      : TRAININGTI~S   =       7

   8._at      : TRAININGTI~S   =       8

   9._at      : TRAININGTI~S   =       9

   10._at      : TRAININGTI~S   =      10

   11._at      : TRAININGTI~S   =      11

   12._at      : TRAININGTI~S   =      12
   ------------------------------------------------------------------------------
                    |        Delta-method
                    |    dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
   -----------------+------------------------------------------------------------
   0.FEMALE         |   (base outcome)
                    |
   -----------------+------------------------------------------------------------
   1.FEMALE         |
   _predict#_at     |
         1  1       |  -.0683392   .0511719   -1.34   0.182   -.1686342    .0319559
         1  2       |   -.056112   .0670928   -0.84   0.403   -.1876115    .0753875
         1  3       |   -.043534   .0919008   -0.47   0.636   -.2236561    .1365882
         1  4       |  -.0307432   .1207787   -0.25   0.799   -.2674651    .2059786
         1  5       |   -.017878   .1516633   -0.12   0.906   -.3151326    .2793766
         1  6       |  -.0050722   .1836001   -0.03   0.978   -.3649217    .3547774
         1  7       |   .0075485   .2160716    0.03   0.972    -.415944     .431041
         1  8       |   .0198701   .2487693    0.08   0.936   -.4677088     .507449
         1  9       |   .0317935   .2815073    0.11   0.910   -.5199507    .5835377
         1 10       |   .0432363   .3141824    0.14   0.891   -.5725499    .6590225
         1 11       |   .0541342   .3467506    0.16   0.876   -.6254844    .7337528
         1 12       |   .0644412    .379209    0.17   0.865   -.6787947    .8076772
         2  1       |   .0403825   .0559415    0.72   0.470   -.0692609    .1500259
         2  2       |   .0252481   .0729637    0.35   0.729   -.1177581    .1682544
         2  3       |   .0099476   .0992688    0.10   0.920   -.1846157    .2045108
         2  4       |  -.0053109   .1288015   -0.04   0.967   -.2577572    .2471354
         2  5       |  -.0203191   .1588791   -0.13   0.898   -.3317165    .2910783
         2  6       |  -.0348759   .1881302   -0.19   0.853   -.4036043    .3338524
         2  7       |  -.0487936    .215706   -0.23   0.821   -.4715696    .3739825
         2  8       |  -.0619028   .2410305   -0.26   0.797   -.5343139    .4105084
         2  9       |  -.0740577   .2637144   -0.28   0.779   -.5909285    .4428131
```

2 10	-.0851392	.2835209	-0.30	0.764	-.64083	.4705517
2 11	-.0950569	.300346	-0.32	0.752	-.6837242	.4936104
2 12	-.10375	.3142007	-0.33	0.741	-.7195721	.5120721
3 1	.0279567	.0362453	0.77	0.441	-.0430827	.0989961
3 2	.0308638	.0456694	0.68	0.499	-.0586466	.1203743
3 3	.0335864	.0625636	0.54	0.591	-.0890359	.1562087
3 4	.0360541	.083882	0.43	0.667	-.1283517	.2004599
3 5	.038197	.1080911	0.35	0.724	-.1736575	.2500516
3 6	.0399481	.1344496	0.30	0.766	-.2235682	.3034644
3 7	.0412451	.162536	0.25	0.800	-.2773196	.3598098
3 8	.0420327	.1920658	0.22	0.827	-.3344094	.4184748
3 9	.0422642	.2228219	0.19	0.850	-.3944587	.4789871
3 10	.0419028	.2546259	0.16	0.869	-.4571547	.5409604
3 11	.0409227	.2873254	0.14	0.887	-.5222247	.60407
3 12	.0393088	.320787	0.12	0.902	-.5894222	.6680398

Note: dy/dx for factor levels is the discrete change from the base level.

D.1.2 Correlations Between Variables in Adoption Models

```
corr FEMALE EXP EDUC HSHLDLABOR DISTANCE LANDOWNED HECTARESRICE TRAININGTIMES E >
XTENSION MEDIA INPUTSUPPLIERS PERSONALSOURCE (obs=394)
             |  FEMALE      EXP     EDUC HSHLDL~R DISTANCE LANDOW~D HECTAR~E
-------------+---------------------------------------------------------------
      FEMALE |   1.0000
         EXP |  -0.0963   1.0000
        EDUC |  -0.2867  -0.0669   1.0000
  HSHLDLABOR |  -0.0114   0.1769  -0.0767   1.0000
    DISTANCE |   0.0289  -0.0363  -0.0600  -0.0138   1.0000
   LANDOWNED |  -0.1497  -0.0165   0.0615   0.1030   0.0760   1.0000
HECTARESRICE |  -0.0964  -0.0500   0.0409   0.0927   0.1708   0.8416   1.0000
TRAININGTI~S |  -0.0418  -0.0145   0.0832   0.0371  -0.0300   0.0032  -0.0106
   EXTENSION |  -0.0125  -0.0767   0.1616   0.0477  -0.0731  -0.0269  -0.0250
       MEDIA |  -0.1257   0.0294   0.1098  -0.0088  -0.0015  -0.0707  -0.0776
INPUTSUPPL~S |   0.0287  -0.0331  -0.1022   0.0211   0.0532   0.1570   0.1334
PERSONALSO~E |   0.0466  -0.0027  -0.1818   0.0031   0.0899   0.0521   0.0813
             | TRAINI~S EXTENS~N    MEDIA INPUTS~S PERSON~E
-------------+---------------------------------------------
TRAININGTI~S |   1.0000
   EXTENSION |   0.3226   1.0000
       MEDIA |   0.0141  -0.1349   1.0000
INPUTSUPPL~S |  -0.1157  -0.3194  -0.3097   1.0000
PERSONALSO~E |  -0.2032  -0.5054  -0.2274   0.1360   1.0000
```

D.1.3 Correlations Between Variables in Pesticide Model

```
. corr FEMALE EXP EDUC LANDOWNED HECTARESRICE HIRELABOR INSECTS ILLNESS DIRECTSEED CROPPA >
TTERN ADOPTB HSHLDLABOR DISTANCE TRAININGTIMES EXTENSION MEDIA INPUTSUPPLIERS PERSONALS
   > OURCE
   (obs=394)

             |   FEMALE      EXP     EDUC LANDOW~D HECTAR~E HIRELA~R  INSECTS  ILLNESS
-------------+------------------------------------------------------------------------
      FEMALE |   1.0000
         EXP |  -0.0963   1.0000
        EDUC |  -0.2867  -0.0669   1.0000
   LANDOWNED |  -0.1497  -0.0165   0.0615   1.0000
HECTARESRICE |  -0.0964  -0.0500   0.0409   0.8416   1.0000
   HIRELABOR |  -0.0192   0.0114   0.0616   0.1028   0.0455   1.0000
     INSECTS |  -0.0843  -0.0930   0.0803   0.0210   0.0307   0.0965   1.0000
     ILLNESS |  -0.0607  -0.2124   0.0339   0.1025   0.1651  -0.0073   0.3414   1.0000
  DIRECTSEED |  -0.1042  -0.1681   0.0145   0.1740   0.1549   0.0916   0.0664   0.2912
 CROPPATTERN |  -0.0121   0.0636   0.0910  -0.0208   0.0667  -0.0347   0.2322   0.0242
      ADOPTB |   0.0513   0.1103   0.0009  -0.1257  -0.1322  -0.0569   0.1473  -0.2072
  HSHLDLABOR |  -0.0114   0.1769  -0.0767   0.1030   0.0927  -0.0397  -0.0389   0.0684
    DISTANCE |   0.0289  -0.0363  -0.0600   0.0760   0.1708  -0.0457  -0.0781  -0.0506
TRAININGTI~S |  -0.0418  -0.0145   0.0832   0.0032  -0.0106   0.0258   0.1385  -0.0034
   EXTENSION |  -0.0125  -0.0767   0.1616  -0.0269  -0.0250  -0.0421   0.1258   0.0256
       MEDIA |  -0.1257   0.0294   0.1098  -0.0707  -0.0776   0.0444   0.1559   0.0088
INPUTSUPPL~S |   0.0287  -0.0331  -0.1022   0.1570   0.1334  -0.0123  -0.2127   0.1121
PERSONALSO~E |   0.0466  -0.0027  -0.1818   0.0521   0.0813   0.0393  -0.0752   0.0451

             | DIRECT~D CROPPA~N   ADOPTB HSHLDL~R DISTANCE TRAINI~S EXTENS~N    MEDIA
-------------+------------------------------------------------------------------------
  DIRECTSEED |   1.0000
 CROPPATTERN |  -0.1680   1.0000
      ADOPTB |  -0.2057   0.1243   1.0000
  HSHLDLABOR |  -0.0388  -0.0636  -0.1034   1.0000
    DISTANCE |  -0.0604   0.0512  -0.0878  -0.0138   1.0000
TRAININGTI~S |  -0.0216   0.1168   0.0375   0.0371  -0.0300   1.0000
   EXTENSION |  -0.0783   0.1791   0.1708   0.0477  -0.0731   0.3226   1.0000
       MEDIA |  -0.0841   0.1420   0.1270  -0.0088  -0.0015   0.0141  -0.1349   1.0000
INPUTSUPPL~S |   0.2537  -0.2108  -0.2471   0.0211   0.0532  -0.1157  -0.3194  -0.3097
PERSONALSO~E |   0.0402  -0.1276  -0.0861   0.0031   0.0899  -0.2032  -0.5054  -0.2274

             | INPUTS~S PERSON~E
-------------+------------------
INPUTSUPPL~S |   1.0000
PERSONALSO~E |   0.1360   1.0000
```

D.1.4 Adoption Model Regression Results with 2 Levels for Adoption

```
1   . logit ADOPTA i.FEMALE EXP i.EDUC HSHLDLABOR DISTANCE LANDOWNED HECTARESRICE TRA >
    ININGTIMES i.FEMALE#c.TRAININGTIMES i.EXTENSION i.MEDIA i.INPUTSUPPLIERS i.PERS >
    ONALSOURCE

    Iteration 0:   log likelihood = -129.39597
    Iteration 1:   log likelihood = -121.38925
    Iteration 2:   log likelihood = -120.53559
    Iteration 3:   log likelihood = -120.53364
    Iteration 4:   log likelihood = -120.53364

    Logistic regression                    Number of obs     =        394
                                   LR chi2(14)       =       17.72
                                   Prob > chi2       =      0.2196
    Log likelihood = -120.53364                  Pseudo R2         =      0.0685
    ------------------------------------------------------------------------------------
          ADOPTA       |     Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
    -------------------+----------------------------------------------------------------
        1.FEMALE       |   .2377447   .4018796     0.59   0.554    -.5499247    1.025414
             EXP       |   .0050613   .0130596     0.39   0.698    -.0205352    .0306577
                       |
            EDUC       |
              1        |  -.0312516   .5316384    -0.06   0.953    -1.073244     1.01074
              2        |    .180953   .5521335     0.33   0.743    -.9012087    1.263115
                       |  -.2845561   .1325083    -2.15   0.032    -.5442676   -.0248446
      HSHLDLABOR       |
        DISTANCE       |  -.0268591   .0360641    -0.74   0.456    -.0975434    .0438251
       LANDOWNED       |   .1056026   .1240696     0.85   0.395    -.1375694    .3487745
     HECTARESRICE      |  -.0535498   .0930409    -0.58   0.565    -.2359066     .128807
    TRAININGTIMES      |   .0677018   .1110909     0.61   0.542    -.1500323    .2854359
                       |
                       |
         FEMALE#       |
    c.  TRAININGTIMES  |
              1        |
                       |  -.0051043   .1905742    -0.03   0.979    -.3786229    .3684143
                       |   .7461408   .4752861     1.57   0.116    -.1854028    1.677684
      1.EXTENSION      |
         1.MEDIA       |   .8560363    .461612     1.85   0.064    -.0487067    1.760779
    1.INPUTSUPPL~S     |  -.3996943   .4415356    -0.91   0.365    -1.265088    .4656997
    1.PERSONALSO~E     |   .4425335   .4386689     1.01   0.313    -.4172417    1.302309
           _cons       |  -2.131928   1.029144    -2.07   0.038    -4.149012   -.1148429
    ------------------------------------------------------------------------------------
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2   . margins, dydx(*)

    Average marginal effects                  Number of obs     =        394 Model VCE    : OIM

    Expression   : Pr(ADOPTA), predict()
    dy/dx w.r.t. : 1.FEMALE EXP 1.EDUC 2.EDUC HSHLDLABOR DISTANCE LANDOWNED            HECTARESRICE
    TRAININGTIMES 1.EXTENSION 1.MEDIA 1.INPUTSUPPLIERS             1.PERSONALSOURCE
    ------------------------------------------------------------------------------------
                       |            Delta-method
                       |      dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
    -------------------+----------------------------------------------------------------
        1.FEMALE       |   .0203288   .0328551     0.62   0.536    -.0440661    .0847237
```

```
            EXP      |  .0004383   .0011308    0.39   0.698   -.0017779    .0026546
                     |
           EDUC      |
             1       | -.0025665    .043909   -0.06   0.953   -.0886265    .0834936
             2       |  .0160697   .0477759    0.34   0.737   -.0775693    .1097087
                     | -.0246433    .011568   -2.13   0.033   -.0473162   -.0019705
       HSHLDLABOR    |
         DISTANCE    | -.0023261   .0031269   -0.74   0.457   -.0084547    .0038026
        LANDOWNED    |  .0091455   .0107615    0.85   0.395   -.0119466    .0302376
      HECTARESRICE   | -.0046376   .0080661   -0.57   0.565   -.0204467    .0111716
     TRAININGTIMES   |  .0056527   .0084819    0.67   0.505   -.0109716     .022277
      1.EXTENSION    |  .0688933   .0470192    1.47   0.143   -.0232626    .1610491
         1.MEDIA     |  .0885475   .0557985    1.59   0.113   -.0208155    .1979105
  1.INPUTSUPPL~S     | -.0333926   .0355838   -0.94   0.348   -.1031355    .0363504
  1.PERSONALSO~E     |  .0380382   .0374199    1.02   0.309   -.0353034    .1113798
---------------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.
```

```
3  . margins, dydx(FEMALE) at(TRAININGTIMES=(1(1)12))

   Average marginal effects              Number of obs    =      394 Model VCE    : OIM

   Expression   : Pr(ADOPTA), predict() dy/dx w.r.t. :
   1.FEMALE

   1._at       : TRAININGTI~S    =        1

   2._at       : TRAININGTI~S    =        2

   3._at       : TRAININGTI~S    =        3

   4._at       : TRAININGTI~S    =        4

   5._at       : TRAININGTI~S    =        5

   6._at       : TRAININGTI~S    =        6

   7._at       : TRAININGTI~S    =        7

   8._at       : TRAININGTI~S    =        8

   9._at       : TRAININGTI~S    =        9

   10._at      : TRAININGTI~S    =       10

   11._at      : TRAININGTI~S    =       11

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   12._at      : TRAININGTI~S    =       12
   ----------------------------------------------------------------------------------
                     |         Delta-method
                     |     dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
   ------------------+---------------------------------------------------------------
   0.FEMALE          |   (base outcome)
                     |
   ------------------+---------------------------------------------------------------
   1.FEMALE          |
   _at               |
           1         |   .0205336   .0334422    0.61   0.539   -.0450119    .0860791
           2         |   .0210419   .0414095    0.51   0.611   -.0601192     .102203
           3         |   .0215331   .0559805    0.38   0.700   -.0881867     .131253
```

4	.0220043	.0747126	0.29	0.768	-.1244298	.1684384
5	.0224524	.0963954	0.23	0.816	-.1664791	.211384
6	.0228744	.1205158	0.19	0.849	-.2133322	.2590811
7	.0232671	.1468503	0.16	0.874	-.2645542	.3110884
8	.0236272	.1752959	0.13	0.893	-.3199464	.3672009
9	.0239517	.205801	0.12	0.907	-.3794109	.4273142
10	.0242371	.2383353	0.10	0.919	-.4428915	.4913658
11	.0244805	.2728746	0.09	0.929	-.510344	.559305
12	.0246787	.3093932	0.08	0.936	-.5817208	.6310781

Note: dy/dx for factor levels is the discrete change from the base level.

D.5. Land Ownership by Pesticide Applications: Bonferroni’s Adjusted Significance Test

```
oneway LANDOWNED PESTICIDEAPPS, bonferroni

                  Analysis of Variance
    Source          SS        df      MS          F     Prob > F
  ------------------------------------------------------------------------
  Between groups    514.126288    13   39.548176     5.40    0.0000
   Within groups    2780.738    380   7.31773157
  ------------------------------------------------------------------------

    Total         3294.86429    393   8.38387859

  Bartlett's test for equal variances:  chi2(9) = 155.4230  Prob>chi2 = 0.000

  note: Bartlett's test performed on cells with positive variance:      4 single-observation cells not used

                    Comparison of S4Q8 by S9Q8
                         (Bonferroni)
  Row Mean-  |
  Col Mean   |      0         1         2         3         4         5
  -----------+-------------------------------------------------------------------
       1     |  1.26535
             |    0.187
             |
           2 |  .755256   -.51009
             |    1.000     1.000
             |
           3 |  1.16539  -.099954   .410136
             |    0.819     1.000     1.000
             |
           4 |  1.12992  -.135425   .374666  -.035471
             |    1.000     1.000     1.000     1.000
             |
           5 |  1.76074    .49539   1.00548   .595344   .630815
             |    0.364     1.000     1.000     1.000     1.000
             |
       6     |   .02807  -1.23728  -.727186  -1.13732  -1.10185  -1.73267
             |    1.000     1.000     1.000     1.000     1.000     1.000
             |
       7     |  3.58474   2.31939   2.82948   2.41934   2.45481     1.824     0.007     0.988     0.182     0.829     1.000
             1.000
             |
       8     |  8.84474   7.57939   8.08948   7.67934   7.71481     7.084
             |    0.113     0.512     0.287     0.466     0.488     0.966
             |
           9 |  2.09474    .82939   1.33948   .929344   .964815      .334     1.000     1.000     1.000     1.000     1.000
             1.000
             |
      10     |  1.94474    .67939   1.18948   .779344   .814815      .184
             |    1.000     1.000     1.000     1.000     1.000     1.000
             |
      12     |  .344737   -.92061  -.410519  -.820656  -.785185    -1.416
             |    1.000     1.000     1.000     1.000     1.000     1.000
             |
      13     |  16.8447   15.5794   16.0895   15.6793   15.7148    15.084
             |    0.000     0.000     0.000     0.000     0.000     0.000
             |
          15 |  .844737   -.42061   .089481  -.320656  -.285185     -.916
             |    1.000     1.000     1.000     1.000     1.000     1.000
  Row Mean-  |
  Col Mean   |      6         7         8         9        10        12
  -----------+-------------------------------------------------------------------
```

7	3.55667 1.000										
8	8.81667 0.248	5.26 1.000									
9	2.06667 1.000	-1.49 1.000	-6.75 1.000								
10	1.91667 1.000	-1.64 1.000	-6.9 1.000	-.15 1.000							
12	.316667 1.000	-3.24 1.000	-8.5 1.000	-1.75 1.000	-1.6 1.000						
13	16.8167 0.002	13.26	8	14.75	14.9	16.5	0.000	0.000	1.000	0.001	0.000
15	.816667 1.000	-2.74 1.000	-8 1.000	-1.25 1.000	-1.1 1.000	.5 1.000					

Row Mean-Col Mean	13
15	-16 0.003

D.6. Adoption Level by Illness: Bonferroni’s Adjusted Significance Test

```
oneway S9Q14W ADOPTB, bonferroni

                    Analysis of Variance
    Source              SS         df       MS            F     Prob > F
------------------------------------------------------------------------
Between groups      8.53663783      2   4.26831892     11.64     0.0000
 Within groups      142.685301    389   .366800259
------------------------------------------------------------------------
    Total           151.221939    391   .386756877

Bartlett's test for equal variances:  chi2(2) =   6.9198  Prob>chi2 = 0.031

                    Comparison of S9Q14W by ADOPTB
(Bonferroni)
Row Mean-|
Col Mean |        0          1
---------+----------------------
       1 |  -.32014
         |    0.000
         |
       2 |  -.12041     .19973
         |    0.837      0.173
```

D.7. Education by Gender: Bonferroni’s Adjusted Significance Test

```
oneway EDUC FEMALE,
  Bonferroni option Bonferroni not
  allowed r(198);
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. oneway EDUC FEMALE, bonferroni

                    Analysis of Variance
    Source             SS        df     MS           F     Prob > F
  ------------------------------------------------------------------------------------------

  Between groups       15.95644     1     15.95644     35.11      0.0000
   Within groups     178.145083    392   .454451742
  ------------------------------------------------------------------------------------------

    Total          194.101523    393   .493897005

  Bartlett's test for equal variances:  chi2(1) =   3.3775  Prob>chi2 = 0.066

                    Comparison of S3Q10N2 by S3Q3N
  (Bonferroni)
  Row Mean-    |
  Col Mean     |        0
  -------------+-----------
       1       |   -.403364
               |     0.000
```