Adoption of Cotton I.P.M. In Zimbabwe:

The Role of Technology Awareness and Pesticide-Related Health Risks

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Introduction

In many countries in Africa, crop protection is centered on chemical control of pests with alternative approaches still in minimal use (Adesina, 1994; Ajayi, 1999). Pesticide use in Africa is largely confined to cash crops (especially cotton and horticulture) where government intervention has unintentionally pushed farmers into a pesticide spiral (Fleischer, 1999). Despite cotton growers' dependency on chemical pesticides via government supported credit programs, the limitations of such pest control measures have become increasingly clear to both farmers and policy makers. Although the application of chemical pesticides has alleviated pest problems in the short term, pesticide use has led to negative externalities such as secondary pest outbreaks, development of pesticide resistance and the destruction of natural enemies, thereby putting farmers in a vicious pesticide treadmill (Burrows, 1983;World Bank, 1996).

Calendar-based techniques are increasingly being questioned for a number of reasons. First, these traditional chemical-based pest management tactics have failed to provide essential ingredients for sustainable crop production, which includes the attainment of multiple benefits such as effective pest control, raising agricultural productivity and minimum damage to the environment. Second, chemical control of pests has elevated occupational health hazards particularly in less developed countries (LDCs) where farmers do not afford protective clothing (Cole et al., 1998; Loewenson and Nhachi 1996; WHO, 1990). Rising concern for public health risks of pesticide use as well as its burden on the environment has added momentum to the need to re-evaluate the current chemical-based pest management practices (Rola and Pingali, 1993). Until the past decade, the debate advocating the substitution of pest control based exclusively on chemicals, with new approaches such as integrated

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The authors gratefully acknowledge financial support from a Rockefeller Foundation African Dissertation Internship Award and a W.K. Kellogg Foundation doctoral fellowship. They also thank Africa University for its institutional support of Dr. Maumbe's field research, as well as Eric Crawford, Carl Liedholm and Chris Petersen for comments on earlier drafts.

pest management (IPM)[2] has not been strong in Africa. Local constituents advocating the protection of the environment and public health are still in their development stages on the continent. Yet the farmers' low level of literacy and education makes the overall risk of exposure to pesticides greater than elsewhere in the world despite the fact that Africa uses about 2% of the world chemical sales (Kiss and Meerman, 1993; Fleischer, 1999).

The benefits of knowledge-based technologies such as IPM in reducing over-application of pesticides thus improving agricultural productivity, human health and the environment have been demonstrated in a number of studies conducted mostly in developed countries (Fernandez-Cornejo, 1998; Swinton, et al., 1999; Norton and Mullen, 1993;Thomas et al., 1990) and also in Asia (Antle and Pingali, 1994) and South America (Antle et al., 1998). The momentum for IPM development is relatively high in Asia but is still very limited in Africa (Adesina, 1994). The general consensus on IPM recognizes that control of pests exclusively with pesticides satisfies a short-term need.

An increasing number of development agencies including the Food and Agriculture Organization (FAO), the International Labor Organization (ILO) and the World Health Organization (WHO) observe that priority should be given to education of pesticide users and promoting systems that restrict or eliminate pesticide use (Weber, 1996). Smallholder cotton growers can make the transition from the use of calendar-based chemical pest management through exposure to Farmer Field Schools (FFS)[3].

The concept of FFS arose from the dual problem of development of pesticide resistance and increasing health risks among farmers in rice–based monocultures in Asia. The FSS philosophy revolves on four principles; (1) growing a healthy crop, (2) weekly field observations, (3) conserving natural enemies of insect pests and (4) understanding the field ecology including water and nutrient management (Fleischer et al., 1999; Braun et. al, 2000). The key objective of FFS is to empower field school participants and make them confident pest experts, self-teaching experimenters, and effective trainers of other farmers (Quizon et al., 2000). In Zimbabwe, this approach is being used to disseminate Integrated Production and Pest Management (IPPM)[4] technology widely viewed as the means to ameliorate the pesticide menace. IPPM, unlike single item innovations such as high-yielding

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[2] IPM is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks (Vandeman et al 1994).

[3] FFS is a participatory training approach that uses discovery-based learning techniques in pest and crop management. Its aim is to help farmer groups understand agro-ecosystems analysis in order to cope with biotic (insect, pests and weeds) and abiotic (water soil and weather) stresses (Rola, undated). Farmer-to-farmer approaches are then used to spread IPM knowledge as the process involves selecting farmers who excel in each FFS group and empowering them to subsequently train other farmers in their own villages.

[4] IPPM combines IPM approaches to manage pests and improve crop production management under mixed farming systems in rural areas of Zimbabwe; it aims to increase crop productivity through interventions in

varieties (HYVs), relies on multiple pest management practices, soil and water conservation, and weather assessments in making pest management interventions. It is essential to understand how such an information-intensive technology is adopted in practice if its prospects for widespread implementation are to be fulfilled.

Although several studies have examined the adoption of IPM in cotton, (Thomas,1990; Ladewig and McIntosh, 1990; Fernandez-Cornejo, 1996; Napit et al., 1988), none addresses the smallholder context and none focuses on Africa. Our study differs from previous studies in that we focus on an emerging innovation still in its early stage of the diffusion cycle in a region that has received no similar systematic studies in the past. This study looks at the adoption of different cotton pest management practices by smallholders in transition from conventional calendar-based chemical pest control to FFS-IPPM strategy. In particular it examines the roles of 1) IPM technology awareness and 2) health experience related to pesticide use.

Problem Overview

The indiscriminate use of toxic pesticides is associated with farmer health and environmental risks. The severe danger from pesticide use implies that a reduction of pesticides has to take place. The development of risk-reducing technologies such as IPM is now the preferred approach in pest management worldwide. Although farmer pesticide use in Africa is relatively low compared to Asia, there are signs of misuse that require urgent solutions. In Asia, heavy pesticide use in food crops especially rice has triggered widespread farmer health problems (Antle and Pingali, 1994). However, pesticide use among smallholders in Africa is associated with cash crop cultivation especially cotton and tobacco (Sukume, 1999). A key question therefore is how can Africa's export crop production avoid the errors of Asia's pesticide misuse. Developed countries have laws and regulations to limit the negative effects of pesticides yet comparable systems of laws and surveillance have been established only recently in LDCs (Frank, 1996).

Given that IPM is viewed as a more effective pest management option, the next question is: How best can it be implemented under smallholder cotton production systems in Africa? The IPM approach has been well received in Asia, Indonesia and Philippines in particular, and it is in Africa's best interest to draw useful lessons from Asia's success with FFS-IPM. The opportunity cost of not adopting IPM is relatively high in LDCs where most farmers using toxic pesticides have the additional burden of being illiterate and lack protective clothing (Kiss and Meerman, 1993). Despite the fact that IPM is widely recommended, it is still not widely used in LDCs (CAB International et al.,1991). For instance, pesticides remain the dominant pest management tactic in most African countries even though the

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both pests and production management.

majority farmers cannot afford pesticides (Ajayi, 1999; Kiss, 1995). Currently, there is little information about actual adoption of IPM in smallholder agricultural production in Africa.

Empirical evidence from Asia where IPM has been well received shows that pesticide use can have negative effects on farmer health causing reductions in farmer productivity (Antle and Pingali, 1994). Assessment of the Indonesia National IPM program and Philippine IPM for rice farmers reveals that IPM is a successful framework for alleviating pest problems leading to higher crop returns and a reduction of both environmental liabilities and human health risks associated with intensive use of agro-chemicals (Rola and Pingali,1993; Cuyno, 1999; World Bank, 1997). In India, pest suppression was found to be more efficient in bio-control-based IPM with consequent increase in cotton yields of up to 33% compared to farmers' practices of plant protection (Rajendran and Bambawale, 1994). However, a slow down in IPM adoption in the Philippines has been attributed to the fact that its benefits are not apparent in the short-run (Rola, undated).

In contrast, empirical evidence on the adoption of IPM in Africa is scant (Jowa, 1993). In Kenya, FFS has empowered local farmers to make more efficient crop management decisions that include assessing crop health and natural enemy activity prior to applying pesticide treatment (Loevinsohn, et al., 1998). The strength of the discovery-based, experimental group-learning model relative to the traditional 'top-down' pest control recommendations is that it takes into account important crop interactions and prevailing field conditions. The FFS approach is now considered the standard procedure to implement IPM in Asia and is slowly spreading to Latin America and Africa (Fleischer et. al., 1999). However, recent studies have raised doubts about the cost effectiveness of FFS approach to combat pests in LDCs (Quizon et. al., 2000).

Zimbabwe cotton offers a useful test case for determinants of IPM adoption among smallholders with and without exposure to comprehensive extension training. Zimbabwe cotton growers make intensive use of pesticides to control major pests such as aphids *(aphis)*, heliothis bollworm *(helicoverpa)*, termites, stainers *(dysdercus)* and red spider mites *(tetranychus)*. Cotton IPM-FFS was initiated among smallholders in the Sanyati district of the Midlands Province in north central Zimbabwe during 1997 with help from FAO's IPM Global Facility. By 1999, two classes of farmers had graduated from FFSs with IPPM training in cotton production. This early stage of IPPM awareness offers a timely opportunity to analyze IPM adoption determinants among Sanyati cotton farmers, including the technology awareness effect embodied in FFS training.

Study Objectives

The main purpose of this study is to determine the factors that influence the adoption of IPM practices in smallholder cotton production in Zimbabwe, and to explore the resulting policy implications.

Knowledge of the key factors driving the adoption of IPM will facilitate policy formulation, program planning and targeting, and diagnosing constraints in existing methods of IPM dissemination. Therefore, the study addresses a serious challenge facing researchers, extension workers and policy makers involved in the development and implementation of an appropriate IPM strategy for smallholder mixed-cropping systems in Africa. Results also provide insights into the prospects for widespread implementation of IPM in Africa. We hypothesize that pesticide-related health risks positively influence IPM adoption. The remainder of the paper will be organized in the following way. First, the evolution and adoption of IPM in LDCs are highlighted. Second, we develop a working definition of IPM for Zimbabwe cotton. Third, we present an economic behavioral model for IPM adoption followed by specification of the empirical model. Next, results of the econometric estimation are presented and discussed. The final section summarizes the paper and discusses key policy implications.

The Diffusion of IPM Technologies in Less Developed Countries (LDCs)

In a few countries where IPM has been introduced in Africa (e.g. cotton in Sudan Uganda, and Zimbabwe is now in IPM mode even if only recently), implementation weaknesses in some instances have been associated with farmer's inability to recognize both key pests and beneficial insects a critical dimension of IPM use. Also in some cases, farmers are unable to distinguish between stress caused by water deficiency and high temperatures relative to that arising from disease and insect damage. However, the impact of factors that constrain early phases of diffusion processes tends to differ and decline as the technology reaches final stage of the diffusion process (Feder and Umali, 1993).

One of the essential aspects of IPM diffusion is the integration of technical and social knowledge (World Bank, 1997). In particular, knowledge about specific pests as well as location specific farm management systems is critical for the successful design and dissemination of IPM approaches. Some major limiting factors to the successful implementation of IPM-related technologies are lack of farmer-focused research and the availability of effective and competitive alternative non-chemical techniques (World Bank, 1997). In many countries, imbalances exist between IPM dissemination and extension curriculum that emphasizes chemical control at the expense of non-chemical options (Pincus et al., 1997).

Apart from Asia, there is also growing evidence of successful development and use of IPM in South America (soybeans in Brazil) (Gallagher, 1988). However, evidence from Ecuador highlights the fact that farmers are at risk of excessive exposure due to widespread ignorance of pesticide poisoning symptoms and lack of personal protective equipment (Crissman et. al., 1994). Therefore, one of the leading concerns of pesticide use in LDCs is that farmer's health is seriously compromised by unsafe application practices (Rola and Pingali, 1993; Tjornhom et. al., 1997). The problems of pest resistance, pest resurgence and emergence of secondary pests in Africa further justify the need for IPM diffusion Kiss (1995).

In Africa, rice IPM pilot programs based on FFS-concept were launched in Ghana, Mali, Cote D'Ivoire and Burkina Faso in1994. Over the past five years, IPM-FFSs have expanded to Sudan, East and Central, and Southern Africa regions. Increasingly, the IPM approach has become popular with both African governments and development agencies interested in broader issues of integrated crop and pest management, and various versions of IPM have been tried in the different countries (Gallagher, 1998).

Despite successes in a few countries, widespread implementation of IPM is still an elusive goal in most parts of the world. The momentum for the diffusion of improved technology such as IPM is slowed by policies that discriminate against agriculture in many countries (Birkhaeuser et al., 1991). Inadequate interaction between policy makers, researchers, extension workers and farmers has inhibited local understanding and adoption of the IPM technologies in Africa (Gallagher, 1998). Besides, the use of Economic Threshold Levels (ETL)[5] on the continent is still underdeveloped and requires refinement (Kiss and Meerman, 1993). Also, IPM technologies oriented toward single pests pose serious weaknesses as the challenge lies with development of ETL for several pests (Rola and Pingali, 1993). Outbreak of secondary pests in Africa makes this approach imperative for successful cotton IPM adoption. Past experience shows that immediate and uniform adoption of agricultural innovations is very rare. In addition, technology adoption and diffusion differs across socio-economic groups and over time (Feder et. al., 1982).

Current Status of IPM Adoption in Less Developed Countries (LDCs)

Experiences from LDCs suggest that successful adoption of IPM on a wide scale requires the following key elements;1) establishing an enabling environment for IPM by eradicating policies in support of environmentally unsustainable pest management and strengthening regulatory institutions, and 2) targeted support for measures that promote the uptake of IPM, such as, public awareness, research, extension and training with an emphasis on decentralized farmer centered initiatives (World Bank, 1997). The desired broad constituency in favor of IPM adoption can be achieved through a clear definition of institutional roles and responsibilities of pest management stakeholders. Also, the World Bank advocates the adoption of a national IPM strategy as crucial for enlisting the necessary commitment to IPM adoption. Such a strategy can secure broad institutional support by addressing

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[5] Economic Threshold Level is the breakeven point at which the dollar value for an increment of loss in yield quantity or quality is equal to the cost of a control method that successfully eliminates pest damage and yield loss (Kiss and Meerman, 1993).

both upstream policy elements and on-farm IPM uptake. The introduction of a national IPM strategy has been adopted relatively easily in countries where research evidence has proved that pesticides are not increasing yields significantly (World Bank, 1997).

Emerging evidence of fiscal unsustainability of FFS poses a major threat to diffusing IPM using such broad-based farmer outreach extension program (Quizon et. al., 2000). Moreover, extensive resources needed to achieve high quality training, a precondition for successful FFS suggests that delivery of IPM through FFS is an expensive venture (Praneetvatakul and Waibel, 2002). An earlier study by the World Bank (1997) observes that a critical constraint to IPM adoption in Sub-Saharan Africa (SSA) is the shortage of low-cost IPM technologies that are relevant to the mixed farming systems prevalent on the continent. The Bank also points out that encouraging a broad base of farmers to experiment with new practices remains a challenge (World Bank, 1997). As the sustainability of FFS becomes questionable, others now advocate the principle of farmer-to-farmer training as a more viable route for expanding FFS outreach while reducing dependency on official donor funding (Quizon et. al, 2000, Braun et. al, 2000). In other parts of the world, the problem of using FFS alumni to facilitate IPM adoption is that such diffusion by former graduates has been found to be gender biased as men diffuse to men and women to women (Loevinsohn, et. al., 1998). Similarly, an age bias among graduates of FFS in SSA has been reported as IPM adoption by older farmers dominates younger farmers (Loevinsohn, et. al., 1998).

In Asia, evidence from Philippines shows that farmers have misconceptions about pests and natural enemies; with leaf eaters generally considered as most important pests. Mismatch between pest damage and responsible pests and confusion between rice and vegetable pests seemed common among farmers. Further, additional IPM adoption hurdle in Asia has been the widespread lack of knowledge about pest resurgence and action thresholds among rice and vegetable farmers (Lazaro et. al.,1995). According to Rola and Pingali, (1993), biological control tended to receive less attention in most IPM activities in Asia. Similar deficiencies were identified in cotton-IPM adoption studies in Uganda where farmers failed to recognize some species of insects as beneficiaries (Kiss, 1995).

Empirical evidence on whether multi-component technology like IPM is adopted individually or in package has been mixed and it still requires further research (Feder and Umali, 1993). Evidence of stepwise adoption patterns of agro-chemical technological components has been reported in earlier studies (Byerlee and Hesse de Polanco, 1986). Conversely, the sequential adoption hypothesis was disputed in a study of maize production in Swaziland where farmers were reported to adopt technologies in clusters (Rauniyar and Goode (1992) cited in Feder and Umali, 1993). A much later study indicates that the adoption decision is inherently multivariate and univariate modeling excludes valuable economic information (Dorfman, 1996). Since, uncertainty about productive performance of a technological package decreases with experience, while confidence increases with positive experience, usually early adopters choose to adopt only parts of a package rather than a complete package (Feder and Umali, 1993). Generalizing adoption patterns is difficult due to differences in technology adoption arising from diverse agro-climatic regions and farmer's socio-economic conditions.

Defining Smallholder Cotton-IPM Adoption

The successful assessment of any IPM strategy begins with a clear definition of what is being assessed**.** Typically, IPM involves a number of pest management practices that are both location and crop specific. There is no consensus in the literature as to what specific pest management practices constitute IPM. IPM definitions have been classified as either "input-oriented" or "output-oriented" (Swinton and Williams, 1998). The latter focus on desired outcomes such as profitability, human health and environmental quality while the former relate to specific IPM practices. Assuming an input-oriented approach, pest management practices can be grouped together and IPM defined as low, medium and high level (Vandeman, 1994; Mullen et al., 1997). Other studies have assigned points to different practices and defined adoption along a scale (Hollings-worth et. al., cited in Swinton and Williams, 1998). Yet others have considered both the proportion of practices and the degree of economic importance of the pest. In our study we use the "input-oriented approach" and focus on the actual number of IPM practices. We characterize the cotton growers in terms of how many IPM practices have been adopted.

For the purpose of this study, the specific cotton IPM and production practices examined include; (1) alternating pesticides to slow development of pest resistance, (2) use of less toxic and safer chemicals, (3) adjusting pesticide application frequency and timing, (4) pest scouting (5) adjusting planting dates, (6) use of beneficial insects in pest management, and cultural practices such as (7) crop rotation, (8) legally enforced closed season (or field sanitation) to stop pest carry-over, and (9) use of trap crops. The potential range of adoption was from 0 to 9. However, we did not ask the farmers to rank the relative importance of each IPM practice.

Methodology and Data

Economic Behavioral Model

Typically, individual households are the primary decision makers concerning agricultural innovations, implying that a household behavioral model is key to understanding the adoption-diffusion process (Feder et al., 1993). Assume the model of an individual household producing multiple crop outputs using multiple inputs that include pesticides. The household maximizes a utility-function $\boldsymbol{U(p)}$ that is increasing in net returns $\boldsymbol{(p)}$ subject to constraints from fixed factors.

Several assumptions are made in specifying the model. First, we assume that farmers consider health costs as cost of production. This implies that farmers do care about both economic and pesticide-related health problems associated with the use of agro-chemicals. Also, agrochemical exposure is assumed to reduce health status of the farmer. Second, cotton production and management decisions can be described as static profit maximization or cost minimization. Third, farmers are sensitive to downside yield risk. Fourth, family and hired labor are homogenous and are considered as perfect substitutes when used in cotton production. The labor market is competitive and the returns to farm work and off-farm work are equilibrated. Finally, we also assume that agro-chemicals contribute to cotton productivity only indirectly via reduction in the population of pests, which are considered in our case as the damage agents.

In that respect, smallholder cotton yields are an indirect function of pesticides applied since production functions that treat pesticides as yield increasing inputs over-estimate marginal productivity. Lichtenberg and Zilberman (1986) were among the first to point out that pesticides should be modeled as damage control inputs just like sprinklers for frost protection. Suppose that the actual cotton yield ***(Y)*** is given by:

$$(1)\ Y = Y^{0}(1\text{-}D\{N(1\text{-}k(X^{p}))\}) \text{ and } Y^{0}= f(p_{y}, p_{x}, K,L,I,Z)$$

where the potential pest-free cotton yield Y^0 is a function of cotton price p_y, prices p_x for all variable inputs including pesticides, labor, fertilizer, seeds, and credit; K is fixed physical capital such as land, L is labor, I is pest management information and Z represents conditioning factors such as soil type, rainfall, farmer's education, gender, experience and managerial capacity. But the actual yield Y, depends on pest damage and its abatement. Therefore, $D(.)$ represents the pest damage function[6], N is the pest pressure and X^p is the pesticide or damage control agent purchased at price p_p**.** Pesticide efficacy range is such that $(0<k(X^p)<1)$ where $k(X^p)$ describes the "kill function". When a chemical is completely effective, that is $(k(X^p)=1)$, then $Y = Y^0$. We also assume that profits are affected by the level of non-pesticide inputs X^o and health services H^s purchased at p_0 and p_h respectively. Following from the work of Antle et al. (1994) and Swinton (1998), we specify the relevant smallholder maximization problem as follows**:**

$$(2)\ \text{Max } p\ (Y, X, H, I) = P_y Y(p_y\, p_x, K, L, I, Z) - p_p X^p - p_0 X^o - p_h H^S$$

$$\text{s.t}\quad (i)\ Y=f(X^p,X^o) - D(N+e)(1- k(X^p)) + m$$

$$(ii)\ EXP=P_a(Q_a - S_c) - w\,(L^e - L_f) + R$$

$$(iii)\ L^e \pounds\ L_f + L_h + L_s$$

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[6] Damage function expresses the relationship between pest pressure and yield loss; it varies with presence of different pests and the abundance of natural enemy species that feed on pests (Rola and Pingali, 1993).

$$(iv) I_t = Y (I_0, FFS, Age, Education, Experience, V)$$

$$(v) H = f (A^{p} H^{s}, I, X^{p}, X^{o})$$

where (i) cotton output (Y) is increasing in non-pesticide inputs X^o, $D(.)$ is a concave and increasing in pest population (N), but N is reduced by concave “kill function” $k(.)$ which is increasing in pest management input X^p. Both cotton yield and pest population are stochastic; $Y+m$ where m~$N(0, s_m{}^2)$ and $N+e$ where e~$N(0\ s_e{}^2)$. Pesticides and non-chemical production inputs are distinguished by variables X^{p} and X^{o} respectively. In equation (ii) EXP is expenditure on non-agricultural products, $P_a\ Q_a$ is cash receipts from agriculture, $P_a\ S_c$ is value of household consumption of self-produced agricultural staple, R is remittances from relatives and w is wage rate, (iii) L^e is total effective labor requirement, L_h is total hired labor input, L_f is family labor and L_s is shared labor from the community. (iv) I_t refers to farmer’s pest information knowledge, I_o represents farmer’s initial level of pest management information before exposure to IPM training, FFS refers to participation in FFS-based IPM training. I_t is also affected by among others farmer’s personal and village level characteristics (V). (v) H is a measure of farmer’s health endowment and A^{p} is pesticide-averting behavior. Beside human health, pesticide use X^{p} also influences environmental quality. However, the data in this study does not provide sufficient farm-level variation to identify this effect, so it is not included in the presentation of the economic behavioral model.

Solving the input and output choice problem, we can derive a factor demand functions for X^{p}, which is stated as follows:

$$(3)\ X^{p} = g (P_y\ P_{x,}, P_h, H, L, I, K, Z)$$

In particular, the demand for IPM practices X^{p} will depend on farmer characteristics, available farm resources (L , K), biophysical characteristics of the farm setting (Z), pest pressure N, institutional and relative prices (P), health effects of pesticides (H) and IPM awareness (I). The specific empirical measures of these attributes are presented in Table 1 and discussed below. It is hypothesized that exposure to IPPM training through FFS will do the following; (i) improve farmer’s cotton pest management knowledge, (ii) raise cotton yields, (iii) lower pesticide use, (iv) improve farmer’s health status and (v) raise farm profitability (Waibel, et al. 1998). The expected outcomes can be summarized as follows:(i)$dI / dFFS\ ³\ 0$, (ii)$¶Y / ¶ I\ ³\ 0$ (iii)$¶X^{p} / ¶ I\ £\ 0$, (iv)$¶H / ¶I\ ³\ 0$, (v)$¶p / ¶I\ ³\ 0$. Adoption analysis of cotton-IPM, a recently introduced technology in Zimbabwe, will provide insights about the important factors driving the uptake of IPM by both the current and future adopters who will ultimately accept the technology. The inclusion of farmers with different years of experience with FFS-based IPPM can form the basis to explore the adoption process itself. Such information will provide more timely strategic adjustments in future IPPM implementation.

Data and Estimation

The empirical model of IPPM adoption among smallholder cotton growers is estimated using cross-sectional data obtained from a survey conducted through personal interviews in Sanyati, one of the leading cotton growing districts in Zimbabwe. Sanyati was one of the first districts to offer FFS-IPPM training to local cotton farmers in 1997. The district is located in the north central part of the country in the Midlands province. It lies in natural regions III and IV[7]. Farmers in Sanyati have a mean cotton growing experience of 14 years. Survey farmers in Sanyati were identified using a stratified random sampling approach on the basis of villages with FFS groups. The second level of stratification was based on the cotton farmer participation in FFS-based IPPM training groups. A total of 141 farmers were interviewed in Sanyati.

Data used in the analysis was collected at two different levels; household and field. The unit of observation was the household. Variables used in the empirical model are based on previous findings from economic theory of adoption decisions (Feder, Just and Zilberman; D'Souza; Dorfman). In addition, univariate adoption models for individual IPM practices provided a further basis for selecting the final variables used in the model. Farmer characteristics that condition adoption behavior include farmer's age **HHAGE**, extension meetings attended **COTEXTMTG**, cotton growing experience **COTYEARS**, level of formal education **EDUYEARS**, gender of the head of household **HGENDER** and whether certified as a Master Farmer **MASTERFM**. We expect farmer characteristics to positively influence IPM adoption although gender effect cannot be established a priori. Also, the age effect can be ambiguous a priori. As age increases hence experience, the time horizon to reap IPM benefits decreases yet experience could lead to better knowledge of IPM and its benefits (Khanna, 2001). Recent evidence from Southeast Asia suggests that older, more experienced farmers tend to show regular attendance at FFS than younger ones (Praneetvatakul and Waibel, 2002).

Farm resource endowment variables include total cotton labor **LABDAYS**, cotton land area cultivated **COTAREA**, value of productive assets **PROASSESTS**, ownership of draft animals **DRAFTOWN**, use of credit **CREDIT** and access to formal off-farm employment **FOMEMPLT**. Farm management practices that could influence pest management include use of improved cotton variety **ALBARFQ902**, production of staple maize crop **ALTCROPM**, whether the cotton field was fallowed the previous season **FALLOW**, absence of specific three-year cotton rotation program **NROTPROG** and number of tillage practices used **TILPRACS** in cotton production. Institutional and relative price factors are access to information media **MEDIA**, average walking time from homestead to cotton fields **AVEWALKT** and distance to cotton markets **DISTMKT**.

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[7] A natural region is an agro-ecological zone demarcated by rainfall pattern, as well as crop and livestock production potential in the region. Mean annual rainfall for NRs III and IV are 800mm and 400 mm.

The health risk variables used to estimate the empirical model are number of pesticide-related acute symptoms **ACUTESYM**, number of individual protective clothing units used by the farmer in making pesticides treatments **SAFINDEX**, measure of farmers ability to rank the toxicity level of pesticides based on color codes on pesticide container labels **LABELIT** and whether or not the head of the household drinks alcohol **HHDRINK**. The last category of the determinants of IPM adoption is the awareness and perception variables. **IPMAWARE** is a measure of post FFS-IPM training years judging from the time when the farmer enrolled. Farmer's perceptions of downside yield risk **YLDRISK** and current chemical-based pest management strategies **PMGTVIEW** were also used in the regression model. All variables and their definitions are listed in Table 3.1.

Empirical Model

In this study, we use a Poisson maximum likelihood regression model to predict the discrete but non-categorical pest management strategies used by cotton growers in Zimbabwe. The shortcomings of using OLS, ordinary probit and or logit analysis in the case of count data are highlighted in the econometric literature (Greene, 1997, Madalla, 1983). The number of additional pest management practices used on a given crop indicates the farmer's reliance on multiple biological and cultural pest management, a key ingredient of IPM use (Vandeman et. al., 1994). Since an integrated package of cotton-IPM as an off-the-shelf system does not yet exist, farmers have the flexibility to combine different counts of practices that address specific pest complex in their fields. The predicted values Y_1 $Y_2, \dots, Y_n$ are assumed to have independent Poisson distribution with parameters $\lambda_1, \lambda_2, \dots, \lambda_n$ respectively (Madalla, 1983). According to Greene, 1997, the basic equation for the Poisson regression is represented as follows:

$$(2)\ Prob(Y_i = y_i) = (e^{-\lambda_i}\lambda_i) / y_i \quad \text{where } y_i = 0, 1, 2, \dots..$$

The parameter λ_i is assumed to be log-linearly related to regressors x_i. Therefore,

$$(3)\ Ln(\lambda_i) = \beta'\chi_i$$

The log-likelihood function is given by :

$$(4)\ Ln\ L = \sum_{i=1,\dots,n} (-\lambda_i + y_i \beta'\chi_i - ln\ y_i!)$$

The expected number of events per period is given by;

$$(5)\ E(y_i / x_i) = Var(y_i / x_i) = \lambda_i = e^{\beta'\chi_i + v_i}$$

Based on the conceptual framework presented the empirical model is estimated using the following groups of explanatory variables; (1) farmer characteristics **(FC)**, (2) farm resource endowment **(FR)**, (3) farm management practice **(FP)**, (4) pest damage **(PD)**, (5) institutional and relative prices **(IP)**, (6) health risk **(HR)**, and (7) awareness and perception variables **(AP)**. Therefore the general form of the empirical model estimated is stated mathematically as follows;

$$(6)\ \sum \text{IPM Practice}_i = \delta\,(FC, FR, FP, PD, IP, HR, AP) + \varepsilon_i$$

Results and Discussion

Farmers' Adoption Patterns and Pest Management Perspectives

The majority of farmers (30%) use at least three IPM practices identified earlier. The mean number of IPM practices used is 4.36. About 11% reported using as many as seven IPM practices in 1998/99. All the farmers reported using at least two IPM–related strategies. The survey contained about 48% of the farmers who had some exposure to FFS-IPPM training. The FFS-IPPM graduates were more likely to be male farmers with high school education cultivating more than one cotton field. A cluster analysis of the different IPM practices did not reveal any discernible pattern in terms of adoption of IPM practices in clusters. The leading IPM practices adopted were field sanitation (97%), crop rotations (87%), scouting (89%), alternating pesticides (32%) and preservation of beneficial insects (30%). Correlation analysis suggests practices were adopted independently. Farmers in Sanyati applied an average of three pesticide treatments on each plot in 1998/99. This suggests either a low level of pest infestation that season or a shift towards more efficient non-chemical pest suppression methods.

An important finding is that cotton growers expressed diverse views about motivations for pesticide interventions and use of IPM. Among those exposed to IPM training, 85% believed that IPM knowledge is an effective pest management tool and 8% felt the opposite. Farmers satisfied with IPM methods constitute a critical mass of the early adopters. The rest were either not sure or had no opinion about IPM. Including the non-FFS graduates, the beliefs about IPM were that 40% felt it was effective while 54% had no idea. The rest felt IPM was ineffective, labor intensive and inferior to the traditional calendar-based chemical control of pests.

Chemical interventions were made for different reasons with 30% of the respondents stating that they spray on fixed calendar basis, while 66% said they applied chemicals only after pest scouting. Other reasons cited for guiding chemical interventions were specific growth stages for the cotton plant. Only 14% of the farmers felt that the major problem in cotton production in Sanyati was pest management. A majority felt that poor prices (53%) were most important, and some felt drought (6%) was a serious problem needing urgent attention.

Factors Affecting Cotton-IPM Adoption Among Smallholder Farmers

Poisson regression results on the determinants of adoption of aggregate IPM practices in Sanyati District are summarized in table 3.2.The analysis was carried out using STATA version 6.0 (STATA, 1997). The Poisson regression model was significant at the 1% level. However, much variability in IPPM practices adopted was not explained by the model, which had a McFadden R^2 of only 10.2%.

The key result of our analysis is the technology awareness coefficient that is significant at the 1% level. Farmers exposed to cotton-IPM techniques through FFS training, are more likely to use several IPM related practices in cotton pest management. A Heckman test on the IPM variable did not reveal any evidence of self-selection. The uniqueness of IPM as a knowledge intensive technology makes the human element an overriding factor in its adoption decisions. Training augments skills and knowledge useful in making innovative decisions. Further it enhances farmer's ability to distinguish technologies that generate opportunities for economic gain from those that do not (Wozniak, 184). The coefficient for the total area cultivated to cotton is positive and significant at the 10% level. This implies a scale-effect in the use of IPM technology in Sanyati. The results suggest that farmers with smaller acreage under cotton are likely to require special adoption incentives such as improved access to technical information to encourage them to use more IPM practices in reducing cotton pest damage. This result matches other several studies that identify farm size as the most prominent variable explaining adoption decisions (Wozniak, 1984; Dorman, 1996)

The coefficient for the cotton variety **ALBARFQ902** is positive and significant at 10%. This implies that farmers growing this drought-tolerant variety are more inclined to use several IPM practices. Additional attributes of this variety are its resistance to bacteria blight and jassids *(empoasca)*, and it is also tolerant to aphids. Although it is susceptible to verticillium wilt *(verticillium dahliae)*, **ALBARFQ902** has the highest score on pest and disease resistance among all the cotton varieties grown in the Middleveld in Zimbabwe.

Contrary to expectation, the pesticide-related health risk variables **ACUTESYM SAFINDEX, LABELIT** and **HHDRINK** are insignificant. The lack of statistical significance associated with health risk variables does not support the hypothesis that IPM adoption decisions are based on pesticide-related health risks. Analysis of IPM adoption decisions of label literate farmers only did not reveal significant relationship between health risks and IPM adoption. Lack of significance could be attributed to the fact that more than 60% of the IPM practices assessed did not use pesticides. Although farmer characteristics estimated from adoption models are important in the policy arena our results also show such variables as insignificant in the adoption of multiple IPM practices. What we may have demonstrated is several variables that can be excluded from consideration when targeting likely cotton IPM adopters under smallholder conditions.

Conclusion

The main conclusion is that technology awareness embodied in access to FFS-based IPM training is really important in motivating the use of multiple components of risk-reducing technologies such as IPM. Investment in IPM farmer education and literacy programs targeted to non-adopters will have long-term beneficial impacts on cotton-IPM use. IPM use requires an experimental cotton plot and farmers with more land are more likely to adopt IPM practices. In addition, cotton growers who planted the drought-tolerant variety **ALBARFQ902** were likely to adopt more IPM practices. Experience with pesticide-related health problems did not significantly affect IPM adoption, suggesting there is still a greater need to sensitize farmers about the health risks of using pesticides. It may be that using IPM does not significantly reduce these risks hence the link between pesticides and human health should be further explored in the context of Zimbabwean smallholders.

Policy Implications and Suggestion for Future Research

Analysis of IPM practices being adopted, the characteristics of smallholders that are adopting and the factors motivating adoption of FFS-IPM is still fragmentary in Africa (Adesina, 1994). Our results indicate that diffusion factors such FFS-IPM training and farmer-to-farmer extension delivery approaches will play a critical role in the delivery and adoption of IPM. Success of IPM adoption will depend on farmer’s knowledge and awareness of the technology. Further, rapid adoption could occur if farmers complement adoption of IPM practices with a conscious choice on HYV varieties that confer drought-tolerance, pest and disease resistance qualities such as **ALBARFQ902**. Both economists and policy makers involved in crafting incentives for widespread diffusion and adoption of FFS-based cotton IPM need to target not only farmers with large cotton acreages but also smaller farmers when planning future IPM programs in Africa. In addition, information about type of farmers most likely to adopt IPM technology and the extent of its adoption is expected to guide agro-chemical firms in their future new product development and marketing strategies given that one of the dimensions of IPM is to emphasizes the use of safer and less toxic products. The pesticide-related health effects require further research to determine their costliness and also their impact on the net benefits of pesticides use under smallholder conditions. As farmers become aware of the health risk costs, it is expected that they will pay more attention to the health factors in IPM adoption decisions. Also, gaps exist in terms of understanding the sequence followed by smallholders in adopting individual IPM practices during its diffusion cycle. Future research must therefore determine the risk-reducing role of individual IPM practices and the bundling strategies used by smallholder cotton growers in adopting compatible combinations of different IPM techniques.

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Table 1.1: Descriptive statistics on variables used in Poisson Regression Model

Variable Name	Definition	Units	Mean	Standard Deviation
Dependent Variable				
Number of IPM practices	Count of IPM practices	count	4.36	1.62
Farmer's Characteristics				
HHAGE	Farmer's age	years	46.25	14.26
COTYEARS	Cotton growing experience	years	14.21	10.37
COTEXMTG	Number of extension meetings	number	4.64	6.36
EDUCYEARS	Number of years in formal education	years	6.57	3.72
HGENDER	Head of household's gender	(0,1)	0.83	-
MASTERFM	Certified Master Farmer	(0,1)	0.26	-
Farm Resource Endowment				
LABDAYS	Total labor used in production	man-day	80.93	43.06
COTAREA	Land area cultivated to cotton	(Ha)	4.55	3.97
PROASSET	Value of productive assets	(Z$)	9,506.41	8,298.98
CREDIT	Farmer used credit	(0,1)	0.18	-
DRAFTOWN	Farmer owns draft power	(0,1)	0.69	-
FOMEMPLT	Farmer is in formal employment	(0,1)	0.47	-
Farm Management Practices				
ALTCROPM	Maize is major alternative crop	(0,1)	0.08	-
ALBFQ902	Cotton variety ALBARFQ902 grown	(0,1)	0.81	-
FALLOW	Field was fallowed previous year	(0,1)	0.42	-
NROTPROG	No specific crop rotation program	(0,1)	0.13	-
TILPRACS	Number of tillage practices	number	1.43	0.87

Cont.

Variable Name	Definition	Units	Mean	Standard Deviation
Pest Damage Variable				
PSTPRESS[8]	Pest pressure (scale 0-1)	index	0.46	0.61
Institutional and Relative Prices				
MEDIA	Farmer has access to information media	(0,1)	0.67	-
AVEWALKT	Average walking time to cotton fields	minutes	12.97	15.78
DISTMKT	Distance to markets	(km)	13.49	7.69
Pesticide-Related Health Risks				
ACUTESYM	Pesticide-related acute symptoms	number	1.13	0.84
SAFINDEX	Count of protective clothing	count	3.75	1.53
LABELIT	Count of correct label interpretation	count	2.16	1.26
HHDRINK	Farmer drinks alcohol	(0,1)	0.48	-
Technology Awareness and Perception				
IPMAWARE [9]	Farmer's experience in FFS-IPM	years	0.83	0.93
YLDRISK[10]	Downside yield risk perception	index	2.61	2.82
PMGTVIEW	Maintain calendar-based methods	(0,1)	0.65	-

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[8] Pest Pressure Index $=\sum$ (pest pressure)/39. The pest pressure indicators are 0=None, 1= Light 2= Average and 3=Severe. The pest pressure is assessed for 13 different cotton pests where a count of 39 represents severe cases for all cotton pests.

[9] IPMAWARE is measured as post FFS-IPM training years; 0=no IPM training, 1= 1998/99 FFS graduate and 2=1997/98 FFS graduate.

[10] Downside yield risk$=(Y_M-Y_L)^2$ where Y_M represents mean cotton yield and Y_L is the perceived lowest cotton yield from the main cotton field during a poor season. The assumption is that farmers care more about downside yield risk.

Table 1.2: Determinants of Cotton IPM Practice Adoption in Sanyati District, 1998/99

Variable	**Coefficient**	**Standard Error**	**Z-value**
Farmer Characteristics			
HHAGE	-0.0002	0.0044	-0.0460
COTEXMTG	0.0072	0.0074	0.9700
COTYEARS	0.0008	0.0058	0.1400
EDUYEARS	0.0100	0.0140	0.7500
HGENDER	0.1200	0.1400	0.8400
MASTERFM	-0.1100	0.1100	-0.9700
Farm Resource Endowment			
LABDAYS	-0.0003	0.0013	-0.2300
COTAREA	*****0.0230	0.0120	0.0190
PROASSET	0.0032E-5	0.0064E-5	0.5000
CREDIT	0.0430	0.1300	0.3400
DRAFTOWN	-0.1700	0.1200	-0.1400
FORMEMPLT	-0.0380	0.1000	-0.3600
Farm Management Practices			
ALTCROPM	-0.1200	0.2000	-0.6100
ALBFQ902	*****0.2600	0.1400	0.0190
FFALLOW	0.1100	0.0960	0.0100
NROTPROG	-0.0580	0.1500	-0.3800
TILPRACS	0.0330	0.0710	0.4700
Pest Damage			
PSTPRESS	0.0030	0.0730	0.0410
Institutional and Environmental			
MEDIA	-0.0540	0.1100	-0.4900
AVEWALK	0.0006	0.0030	-0.1900
DISTMKT	0.0066	0.0081	0.8200

Pesticide-Related Health Risks			
ACUTESYM	0.0200	0.0650	0.3100
SAFINDEX	0.0340	0.0340	0.9900
LABELIT	-0.0150	0.0390	-0.3800
HHDRINK	-0.1000	0.1100	-0.9500
Technology Awareness and Perception			
IPMAWARE	*******0.1900	0.0670	0.0290
YLDRISK	-0.0080	0.0170	-0.4600
PMGTVIEW	-0.0370	0.1000	-0.3500
N	**136**		
McFadden R-squared	**0.1022**		
Log Likelihood Ratio	**53.32**		
χ^2 **-p value**	**0.0027**		

*=significance at 10%, **=significance at 5%, ***=significance at 1%

Source: Field survey, 1999

Table A1.1: Cotton IPM Practice Probit Model Results for Sanyati District, 1998/99

Variable	Beneficial Pests	Cotton Rotation	Adjust Planting Dates	Adjust Spraying Frequency	Alternate Chemicals	Safer Chemicals	Trap Crops
Farmer Characteristics							
AGE	+ **	+	+	-	-	+	-
EDUCYEARS	+ **	+	+	+ ***	+	+	-
GENDER	-	-	-	+	+	+	+
COTYEARS	+	+	+	+	+	- *	+
Pesticide-Related Health Risks							
ACUTESYM	+	+	+	+ *	-	+	-
ALCOHOL	+	-	- **	+	-	-	- *
PCLOTHES	+ *	+**	- **	+	+	+	+
Farm Resources							
COTAREA	+ ***	+	-	+ **	+ ***	+ **	+
DRAFTOWN	-	-	- *	-	-	-	- **
LABOUR	-	- **	+	+	-	-	-
PROASSETS	+	-	+	-	+	+	+
FORMEMPL	-	-	+ **	-	-*	+	+
Farm Practice(s)							
TILLAGE	- **	+	+	-	- *	+	-
Pest Damage							
PSTPRESS	+	-	-	-	-	+	-
Institutional							
CREDIT	- ***	+	+ *	-	-	-	+
COTEX	+	-	+ ***	+ **	+ ***	+	-
MEDIA	+	+	+ **	-	-	- ***	+
Technology Awareness & Perception							
IPMAWARE	+ ***	-	+	+	-	-	+ ***
IPMVIEW	+	+	+ ***	+ ***	+*	+ ***	-
YLDRISK	- *	- **	+	-	+**	+	- **
PMGTVIEW	-	+	- **	+	-	- *	+ *
GROWSTRG	+ **	-	-	-	+	-	+
N	138	138	138	138	138	138	138
McFadden R^2	0.62	0.36	0.43	0.43	0.26	0.43	0.60
L.L. Ratio (χ^2)	106.08	32.90	58.5	65.75	45.76	55.90	67.16
χ^2-p value	0.00	0.06	0.00	0.00	0.00	0.00	0.00

Source: Field Survey, 1999

Table A1.2: Cotton IPM Practice Probit Model Results for Chipinge District, 1998/99

Variable	**Cotton Rotation**	**Adjust Planting Dates**	**Adjust Spraying Frequency**	**Pest Scouting**	**Alternate Chemicals**
Farmer Characteristics					
AGE	-	+	-	+	+
EDUCYEARS	-	-	-	+	+
GENDER	-	+	-	+	+
COTYEARS	+	-	+	+	+
Pesticide-Related Health Risks					
ACUTESYM	-	-	+ *	+	+
ALCOHOL	+	-	-	-	-
PCLOTHES	-	+	-	-	-
Farm Resources					
COTAREA	+	+	+	+	+
DRAFTOWN	+	-	-	-	-*
LABOUR	+	-	-	+*	+
PROASSETS	-	-	-	+	-
FORMEMPL	+	- *	-	-	+
Farm Practice(s)					
TILLAGE	+	+	+	+*	+
Pest Damage					
PSTPRESS	-	-**	-	-	-
Institutional					
CREDIT	+	+ *	+	-	+
COTEX	-**	-	- ***	-	-
MEDIA	-	-	-	+	-
Technology Awareness & Perception					
YLDRISK	+	-	-	-***	-*
PMGTVIEW	+	+*	+	+**	+***
GROWSTRG	-	+	+***	+	+***
N	130	130	130	130	130
McFadden R^2	0.17	0.19	0.37	0.30	0.22
L.L. Ratio (c^2)	28.97	29.41	47.34	45.80	35.86
c^2-p value	0.08	0.08	0.00	0.00	0.00

Source: Field Survey, 1999

Note: Probit model for burning stover (field sanitation) was insignificant. No farmer used beneficial insects and trap crops as pest management strategies while less than 10% reported using safer chemicals in their pest management decisions, thus making it statistically impossible to estimate probit models based on such rare practices in Chipinge District.

Table A1.3: List of Cotton IPM-related Practices Used in Survey Areas, 1989/99

COTTON IPM-RELATED PRACTICES	**SANYATI DISTICT (%)**	**CHIPINGE DISTRICT (%)**
A. Biological Control		
1.Beneficial insects	31	0
B. Cultural Control		
2.Crop rotations	87	41
3.Field sanitation	97	91
4.Trap crops	14	0
C. Selective Chemical Control		
5.Alternating chemicals	32	31
6.Use of safer chemicals	18	7
7.Adjust frequency and timing of pesticide sprays	23	18
D. Strategic Control		
8.Adjust planting dates	19	28
9.Pest scouting	89	71

Source: Field survey, 1999