DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

WORKING PAPER

A Farm Level Evaluation of the Impact of IPM on Pesticide Use: A Comparative Analysis of IPM and Non-IPM trained farmers in Zimbabwe's Smallholder Sector

by

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Abstract

Smallholder farmers constitute the majority of farmers in Zimbabwe. Their production systems are predominately subsistence based, in which maize accounts for over 65% of the cultivated area. Horticultural production has steadily grown to become an important additional source of income for smallholder farmers who are being encouraged to diversify to the production of high value crops. Tomatoes are an important crop grown by smallholder horticulture farmers.

Tomato production is vulnerable to pests and disease outbreaks. Currently, pest management in tomato production is characterized by a heavy dependence on chemical pesticides. Chemical pesticides are viewed as a quick and easy solution to pest problems. In Zimbabwe, and in many developing countries, chemical pesticides receive a substantial amount of government support as they are seen as the main means of reducing crop losses. However, there is mounting evidence of the negative effects of chemical pesticides on human health and the environment. Toxic substances can accumulate in the ecosystem and have a detrimental effect on non-target organisms.

Integrated Pest Management (IPM) promotes the use of all known (biological and cultural) environmentally benign pest control measures. Farmers are encouraged to integrate the various biological and cultural methods such that chemicals are used minimally and very judiciously. In Zimbabwe, very few farmers have had exposure to IPM because it has not been widely promoted. Given an increase in cost of agricultural inputs (including chemical pesticides) in Zimbabwe, there could be scope for wider adoption of IPM.

This study presents a preliminary assessment of the impact of IPM technology on farmers' pest control practices, perceptions of chemical pesticides, and knowledge of non-chemical pest control alternatives. The study involved a comparative analysis of 84 non-IPM trained smallholder tomato growers and 36 IPM trained smallholder tomato growers. The farmers were surveyed in 1999 in Chinamora communal area, a horticulture farming area 50 km to the North -east of Harare.

The study findings indicate some promising implications for wider adoption of IPM by smallholder farmers. IPM training had a positive influence on farmers' knowledge level of pests and health hazards of chemical pesticides and a negative influence on the amounts of chemical pesticides used. IPM trained farmers spent 57.5 % less on chemical pesticides than farmers not trained in IPM. Nearly all (99%) IPM trained farmers knew of the five major pests of tomatoes compared to 76% of the non-IPM trained farmers. More IPM trained farmers knew and used alternatives to chemical pesticides to control pests. IPM trained farmers anticipated yield losses of 60% due to pest damage compared to 95% perceived by non-IPM trained farmers. IPM trained farmers were more aware of both the acute and the chronic illnesses associated with exposure to chemical pesticides than non-IPM trained farmers: 80% of IPM trained farmers compared to 5% of the non-IPM trained farmers were aware.

The study concludes that policy makers should encourage the use of a pest management strategy that is information based such as IPM. This will improve the smallholders' effective use of chemical pesticides increasing their profitability and will raise the farmers' awareness of the health hazards of chemical pesticides.

Keywords: *IPM, Zimbabwe, pesticides, perceptions, awareness*

I. Introduction

In recent years smallholder maize productivity and production has been declining and rural households are threatened by persistent food insecurity. A strategy being encouraged in Zimbabwe's communal areas is to diversify and grow high value horticultural crops to earn more farm income and improve livelihoods. Among the horticultural crops grown by smallholder farmers, tomatoes are an important crop. For example, it is the most commonly grown horticultural crop in the Mashonaland East provinces of Zimbabwe, where it is grown by 90% of smallholder farmers (Turner and Chivinge, 1999). The tomato crop is highly vulnerable to pests and disease attacks. Use of chemical pesticides has been the ultimate recommended solution until IPM was introduced as an alternative pest management strategy. In 1997 IPM training program for farmers was initiated in the country by different institutions. It is important to investigate the benefits of such training and draw lessons for wider adoption by the many farmers that are growing horticultural crops as alternative source of income in Zimbabwe.

Objectives of the study

The main objective of the study is a preliminary socio-economic assessment of the impact of IPM training on smallholder farmers by comparing IPM trained farmers (IPM farmers) and farmers who did not receive training on IPM (NIPM farmers).

Methodology

The study draws from a household survey of 36 IPM farmers and 84 NIPM farmers conducted in Chinamora during the month of February of 1999. The survey area, Chinamora was purposely selected. It was selected because 1) it was known that there were some farmers trained in IPM technology 2) because it is an important vegetable producing communal area where high amounts of chemical pesticides are used. The survey targeted household heads for interview. IPM farmers were randomly selected from a sampling frame containing a list of all group members kept by a Farmer Field Worker. A sampling frame for NIPM farmer did not exist. A random sample of NIPM farmers was selected through enumerators choosing every tenth household they came across as they walked across the villages. Enumerators had to establish that the farmers grew tomatoes before proceeding with the interviews.

Study layout

The paper is divided into four sections. Following the introduction, which outlined the study objectives and methodology, section two discusses the background on use of chemical pesticides and IPM training in Zimbabwe's smallholder sector. The third section presents the results, analysis and discussion of the field survey. The final section draws conclusions and relevant recommendations.

II. Background and Review of Chemical Pesticide use in Zimbabwe

Since the onset of the green revolution, pesticide use in developing countries has spread dramatically. Governments, in their endeavors to accomplish goals such as self-sufficiency by raising crop production, promoted the use of chemical pesticides. Chemical pesticide use received support from governments because chemicals were viewed as a quick and efficient solution for controlling pests (Agne et al 1995). The sustainability of chemical pesticides in controlling pests has recently been under doubt in the wake of increasing problems of pest resurgence and increasing evidence of the health and environmental hazards of chemical pesticides. The negative side effects of chemical pesticide include, poisoning of users (farmers), chronic health effects, pesticide residue in food and drinking water and damage to the natural environment.

Chemical pesticides have induced changes on the agricultural systems and ecosystems, with negative consequences, such as pest resistance and destruction of beneficial organisms. Even though chemical pesticide use on a world scale increased steadily in the last four decades, crop losses were not reduced correspondingly (Pimentel et al, 1993 in Jungbluth, 1996). The many shortcomings associated with dependency on chemical pesticides have prompted development of the concept of integrated pest management (IPM). IPM is a management strategy combining several environmentally benign pest control techniques such as use of natural predators, biological pesticides and adapted cultural practices, including breeding plants for pest and disease resistance, with a diminished and less frequent utilization of chemical pesticides (Farah, 1994). The concept of IPM is seen as a valuable alternative to the indiscriminate spread of chemical pesticides. However, several factors contribute to a sluggish adoption of this technology. An important reason why IPM is not widely practiced in developing countries is that the current economic environment and government policies related to pesticides, and to pest management in general, induce an excessive (above the socially optimal level) chemical pesticide use (Agne et al, 1995).

Chemical Pesticides use in Zimbabwe's Small holder sector

Smallholder farmer's of chemical pesticides is relatively low as compared to large-scale commercial farmers. For example, they accounted for 20-30% of insecticides, 1-5% of herbicides and 2-3% of fungicides used in Zimbabwe between 1986-91 (Mudimu et al, 1995). The smallholder farmers' use of chemicals has been on the increase, as they have been encouraged to diversify into commercial production to raise their farm incomes. Many are engaging in the fast growing horticultural sector. Between 1986 and 1993 vegetable production accounted for 3% of insecticides, 24% of fungicides and 20% of regulators used in Zimbabwe (Mudimu at al, 1995). Since 1995, the horticultural sector and the use of chemical pesticide in Zimbabwe have expanded tremendously. For example the total value of all chemical pesticides used in Zimbabwe increased by 397% from Z$ 431 million in 1995 to Z$ 2,142 million in 2000 (ACIA, quoted in Singh and Muzorewa, 2001).

Information available indicates that smallholder horticulture farmers in Zimbabwe face difficulties in pest management (Turner, 1997). Most of the horticulture farmers rely on chemical methods to control pests. Over 70% of these farmers, most of whom are women, have shifted from employing traditional crop protection practices, they now rely on chemical control yet have inadequate training on proper application (Turner, 1997). Farmers lack training and adequate information to properly utilize pesticides. The consequence of this is that farmers tend to abuse and overuse chemical pesticides (Turner, 1997). Because of the inability to identify pests correctly, farmers often apply inappropriate chemicals. In a survey of communal farmers growing tomatoes in Chinamora, 40% were found to be using fungicides against insect pests e.g red spider mite and some farmers (4%) were using insecticides in attempts to control fungal diseases (Sibhensana, 1996). Most farmers in a bid to avoid risk of crop pest damage apply chemical pesticides prophylactically before there are even any indications of pest problem (Sibhensana, 1996). According to Sithole and Chikwenhere (1995), most farmers are not aware that this over use of pesticides is rapidly bringing about development of pest resistance to most commonly used chemicals particularly insecticides.

Chemical pesticides expose farmers and consumers to poisoning. Most tomato-growing farmers in Chinamora spray chemicals without protective clothing. The reasons for this, according to Sibhensana (1996) include that they cannot afford the protective clothing and some thought washing oneself after spraying is an adequate precautionary measure against chemical poisoning. According to Sithole and Chikwenere (1995) many smallholder farmers do not allow the recommended time to elapse between applications nor from spray to harvest interval, posing a threat to consumers of their produce due to unsafe levels of chemical residues. While most smallholder growers apply chemicals willy-nilly they are not aware of other management strategies that they can use together with chemicals to effectively reduce pest populations (Vambe 1997, quoted in Jackson et al, 1997).

IPM training in Zimbabwe

In Zimbabwe most smallholder farmers lack any sort of training in IPM (Turner, 1997). A need to train farmers on IPM methods has been recognized in Zimbabwe. At the national level, the Ministry of Agriculture, through the support of FAO initiated a national programme to disseminate IPM technology to smallholder farmers in 1997. IPM technology is mainly targeted to cotton growers through the Farmer Field School approach.

In vegetable production two NGOs , Cornell Institute for International Food and Agricultural Development (CIIFAD) and Zimbabwe Institute for Permaculture (ZIP) initiated programs to disseminate IPM technology to smallholder vegetable growers. CIIFAD in collaboration with national Universities, NGOs and the national extension service initiated a national IPM plan in May 2000.

In the survey area Chinamora, ZIP provides training in IPM to some of the farmers. ZIP is a Zimbabwean NGO dedicated to providing training and research in Natural Pest Management for communal farming sector. It disseminates the IPM technology via an approach similar to Farmer Field School approach. Training is given directly to Farmers Field Workers (FFW) rather than to extension workers. FFW are selected by their communities for their leadership abilities. The FFW receive an initial month-long training in Natural Pest Management and organic farming in ZIP's Eco-Lab. The Farmer field School takes place in the farmers' own field with support from ZIP research staff. IPM technology is yet to diffuse to the majority of the smallholder farmers.

III. Results and Discussion

The Survey area

The survey area is located 50 Km North-east of Harare (Figure 1). It lies in Natural Region Iia, which receives 750-1000mm summer rainfall with a good distribution. The area is generally wet with a lot of streams and springs such that during the dry season there are many water sources for irrigating crops. The soils are also reasonably fertile making it very suitable for intensive horticulture production. The area is serviced with a fairly good road network linking it to the capital Harare.

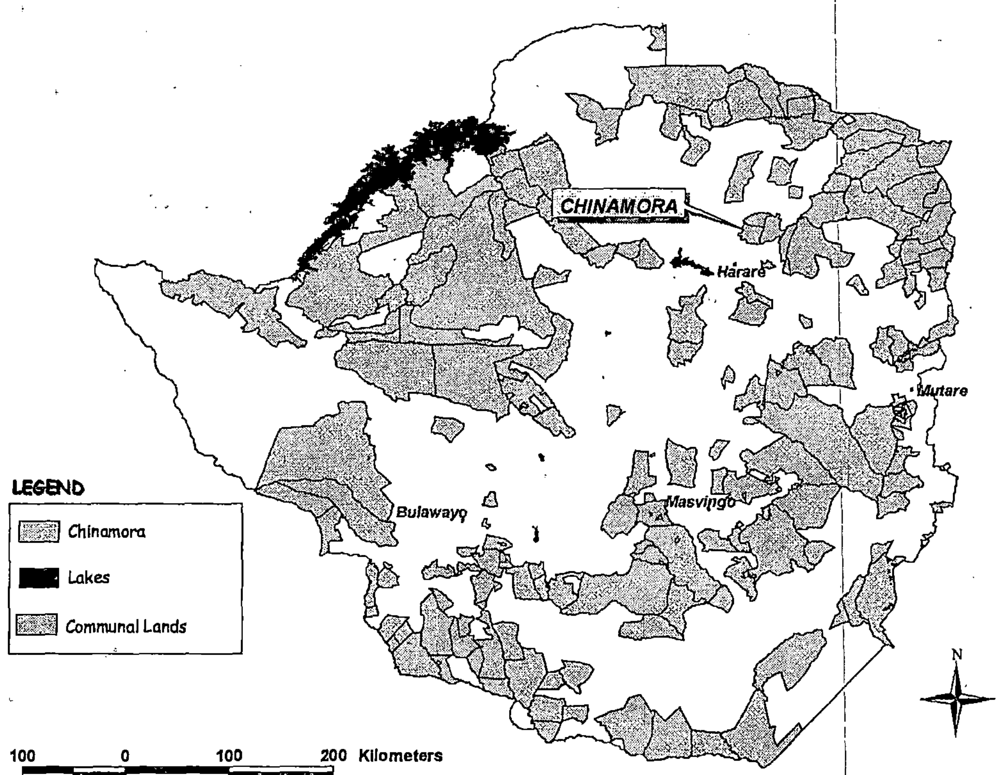

Figure 1. A map of Zimbabwe showing the relative location of the study area, Chinamora

Characteristics of surveyed farmers

All the IPM farmers had two years of practicing and experimenting with IPM methods. They started their training in 1997.The IPM farmers and NIPM farmers were found to be similar in terms of the major characteristics that were assessed (Table 1). The only significant difference was in the percentage of male farmers. There was a higher proportion of female household heads amongst the IPM surveyed than the NIPM farmers. This could be due to the fact that usually women are more keen than men to join farmers' groups. In addition, a woman FFW led IPM farmers in this survey group.

Table 1. Characteristics of surveyed farmers

	IPM	NIPM
	Mean (n=36)	Mean (n=84)
Sex (% male)*	40	62
Age (mean years)	39	42
Years of formal education	7.9	8
Total land Holding (ha)	2	2.1
Tomato hectarage (ha)	0.23	0.25
Annual cash income ($)	13,678	14,985
Household size	6	6

(Difference significant at 95% confidence level)

Knowledge of tomato pests

Knowledge of both chemical pesticides and pests is very critical if farmers are to effectively utilize the chemical pesticides to control pests damaging their crops. Lack of this knowledge may result in farmers employing inefficient chemical spraying practices such as: 1) applying wrong chemicals; 2) applying chemicals as a 'cocktail' and 3) prophylactic application of chemicals.

IPM and NIPM farmers were compared in terms of their knowledge of the five most important pests of tomatoes (Table 2). Exposure to IPM training significantly influences farmers' knowledge of tomato pests. The proportion of IPM that had knowledge and ability to identify the five most important pests of tomatoes was significantly higher than that of NIPM farmers (Table 2).

Table 2 Knowledge of five most important pests of tomatoes

Do you know this pest	IPM % Yes	NIPM % Yes	$\chi2$ p Value
Red Spider Mite	100	80	0.003
Cutworm	100	80	0.004
Fruitworm	97	70	0.000
Bacterial Speck	97	70	0.001
Early Blight	100	79	0.003

Perceptions on Productivity effects of chemical pesticides

According to Rola (1997), productivity of pesticide can be represented by the shift in yield from a pest-infested yield to the actual yield the farmer obtains after use of pesticide other factors held constant. This yield gain or loss abatement effect of pesticides will depend on how effective the pesticides are used. Farmers generally do not measure this productivity though they may have perceptions about the magnitude of the yield gain. This study elicited and compared the perceived magnitude of yield loss due to pest damage loss under three pest control regimes, namely 1) use of non-chemical pest control means 2) the farmer's actual practice and 3) intensive use of chemical pesticides were elicited (fig.2).

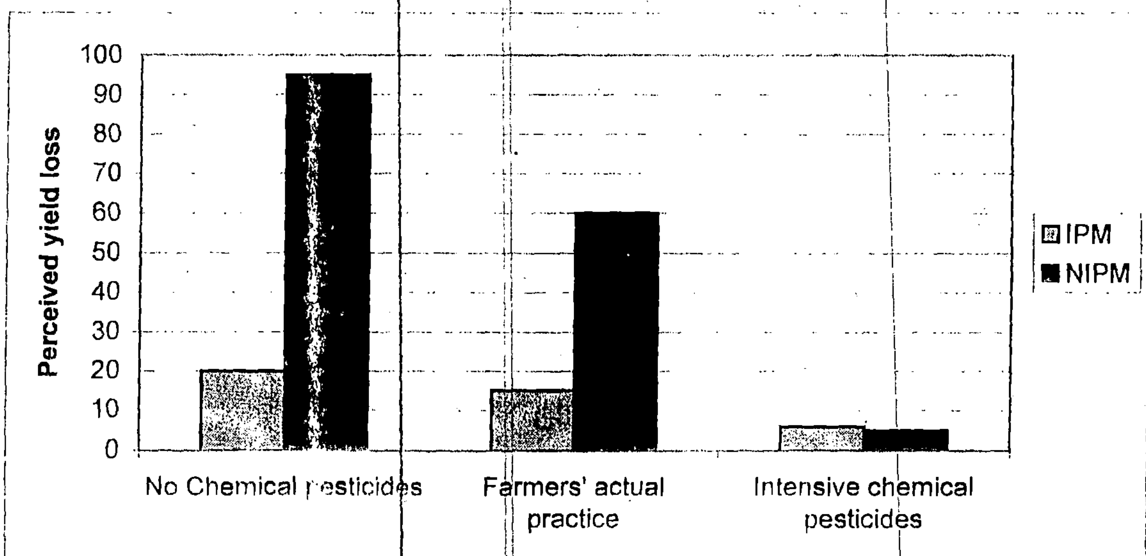

Figure 2 IPM and NIPM farmers' perception of yield loss due to pest damage

Both IPM and NIPM farmers perceive that yield loss can be reduced to just 5% of potential yield if chemical pesticides are used intensively. IPM and NIPM farmers' perceptions of yield loss differed markedly for a situation where chemical pesticides use is totally eliminated. Under none use of chemical pesticides, NIPM farmers perceived yield losses of up to 95% of potential yield compared to just 20% perceived by IPM. The huge difference in this perceived yield loss can be explained by the fact that IPM farmers have knowledge and experience in use of a range of equally effective non-chemical pest control means unlike NIPM farmers who are dependent almost exclusively on chemical pesticides.

Use of chemical pesticides

IPM and NIPM farmers used two types of pesticides; insecticides and fungicides in controlling tomato pests. Both groups of farmers did not use herbicides. Farmers reported using a wide range of brands of both fungicides and insecticides (Table 3).

Table 3 Quantities of chemical pesticides used per hectare per season

Pesticide	**IPM**		**NIPM**	
	Mean/ha	**Users (%)**	**Mean/ha**	**Users (%)**
Insecticides				
Rogor (L)*	0.47	28	1.62	69
Carbaryl (Kg)*	0.56	28	1.66	46
Mitech (L)	0	0	1.11	18
Dicofol (L)	0	0	0.68	18
Karate (L)	1.2	14	1.16	36
Fungicides				
Dithane M45 (Kg)**	4.4	30	9.74	83
Copper Oxychloride (kg)**	2.56	28	5.06	65
Lime Sulphur (L)	0.17	8	1.41	26

(Difference significant * at 10% **5% significance levels)

IPM farmers practiced a range of non-chemical pest control measures. Only a few NIPM farmers practiced non-chemical means of controlling pests (Table 4). NIPM farmers did not use this range of non-chemical means, largely because they are not aware of them. Most of the non-chemical pest means used by IPM farmers comprise easily available and cheap natural substances. For example, IPM farmers have since realized that the ashes they collect from their fireplaces are quite effective in controlling fruit quality-reducing bacterial and fungal infestations. This explains why IPM farmers used markedly less amounts of fungicides as compared to NIPM farmers. IPM also used some botanical pesticides, which they brew from leaves and other vegetative parts of some locally occurring plant species. For example they used a brew prepared from leaves of a local shrub known as Chowa (*Datura stramonium*) to control aphids, a common insect pest of tomatoes.

Chemical spraying methods

To make effective and economical use of pesticides, just the minimum amount required to abate yield loss should be used. A rule of thumb is that farmers should use judicious amount of pesticides that do not compromise the yield of tomatoes i.e. spray only when it is really necessary. Scouting to assess the level of pest infestation then spraying only after a certain threshold level of infestation is observed provides a practical option for achieving an economic level of pesticide use. Spraying regularly after some fixed time interval, which is the current recommendation, does not guarantee economical use of pesticides. Scouting is however, information intensive, it requires that farmers should be able to identify the pests and have an understanding of their potential to reduce yields.

Tomato farmers in Chinamora follow about 3 types of spraying regimes. A majority (64%) of the NIPM followed a fixed spraying program while a majority (60%) of the IPM sprayed after scouting. Some of both IPM (11%) and NIPM (18%) farmers combined a fixed program with spot spraying (Immediately after pests are noticed) (Table5).

Table 5 Chemical spraying methods

Spraying Strategy	IPM	NIPM
	%	%
After scouting	60	15
Follow a fixed program	27	64
Program + when pests are noticed	11	18

Because IPM farmers had knowledge of pest ecology, they had the leeway to follow a chemical-pesticide intervention option that offers a chance of using this costly input more judiciously. NIPM farmers probably overused-pesticides, by spraying when not necessary or used the wrong chemical pesticides as they had less knowledge of the pest attacking their tomatoes.

Willingness to reduce chemical pesticides use

IPM farmers and NIPM farmers were assessed on their willingness to reduce the amount of chemical pesticides they currently used. The willingness to reduce chemical pesticide use was significantly ($p< 0.001$) related to whether or not farmers were exposed to IPM training (Table 6).

Table 6: Willingness of farmers to reduce intensity of chemical pesticides use

Use of chemical pesticides	IPM	NIPM
	%	%
No chemical pesticides at all	92	1
Moderate use of chemical pesticides	8	60
Intensive use of chemical pesticides	0	39
χ^2p value = 0.00		

IPM farmers were more willing than NIPM farmers to reduce the amount of chemical pesticides used in tomatoes. The reason is probably because they were more aware of the health and environmental hazards of chemical pesticides and at the same time had more knowledge of less harmful pest control practices

Behavior when lacking knowledge of pest attacking tomato crops

Often farmers may find themselves in a situation whereby they lack knowledge of some pests or disease affecting their tomatoes. Whether or not farmers decide to seek more information and the source of that information may influence the amount of chemical pesticides they use. IPM farmers and NIPM farmers were asked as to what they would do if they did not know the pest affecting their tomato crop (Table 7).

Table 7 Farmer's next step if they have no knowledge of tomato pest

Action	**IPM**	**NIPM**
	%	%
Ask extension workers	11	60
Ask fellow farmers	86	33
Ask sales agent	-	2
Try out different chemical pesticides	-	5
Try out different non-chemical methods	28	-

Most NIPM farmers would seek information from external agents (extension workers and sales agents) while most IPM farmers would seek information from fellow farmers practicing IPM principles (Table 7). This implies that IPM trained farmers have some capacity to apply and share IPM practices independent of external agents. Loevinsohn et al (1998) made similar findings in smallholder farming systems of Kenya where IPM trained farmers were observed to be more independent in their decisions to control pests than farmers not trained in IPM. Often the external sources (AREX extension officers, agrochemical company sales agents) of information in the survey area, and in Zimbabwe in general, are pro-chemical pesticides use.

Some NIPM farmers (5%) revealed a tendency to abuse chemical pesticide by trying out different chemical pesticides when they don't know the pest attacking their tomatoes. On the other hand, some IPM farmers(28%) experimented with different non-chemical pesticide methods when they do not know the pest attacking their tomatoes.

Perceptions on health hazards of chemical pesticides

Many chemicals used in agriculture give rise to allergic reactions, eczema, problems with mucous membranes etc (Christiansson, 1991). In Zimbabwe about 50% of workers on large scale farms involved in pesticide use are exposed to organophospates during spraying season (Nhachi, 1999). Unfortunately there is no drug that one can take to prevent organophosphate poisoning (Singh and Muzorewa, 2001). There were 606 cases of organophosphate poisoning between 1980 and 1990 recorded in six central hospitals in Zimbabwe (Chivinge et al, 1999). The increase in organophosphate poisoning in Zimbabwe from 1980 was found positively correlated to an increase in acreage under cultivation (Nhachi, 1999).

It is generally easier for farmers to notice the acute health problems than chronic health problems association with chemical pesticide use. IPM farmers were more aware of both acute and chronic health problems associated with chemical pesticides than NIPM farmers (Table 8).

Table 8 Farmer's awareness of the linkage between health problems and pesticide use

	IPM	NIPM	Proportions test
	%	%	P values
Eye infection **	90	70	0.0507
Respiratory problems***	80	50	0.0086
Skin irritations***	100	80	0.0086
Cancer***	50	10	0.0000
Heart diseases***	60	5	0.0000
Headaches	100	90	0.1292

(***, **, * differences significant at 1%, 5%, 10% significance levels respectively)

A significantly larger proportion of IPM farmers were aware of the association between the acute (except in the case of headaches) and chronic health problems and exposure to chemical pesticides than NIPM farmers. The difference in level of awareness of health hazards of chemical pesticides between IPM farmers and NIPM farmers is largely attributable to exposure to information. IPM farmers' knowledge of health hazards is not only limited to their experience, but they received additional information during training and they continued to share the information in groups. This is especially true for the awareness of long-term illness caused by chemical pesticides such as heart diseases and cancer.

Perception of environmental dangers of chemical pesticides

Literature is awash with evidence that chemical pesticides are harmful to the environment. These hazards include, among others, poisoning of non-target species, and accumulation of toxic substances in the water bodies. Between 1913 and 1923 there were many cases of animal poisoning in Zimbabwe due to arsenic caused by use of chemical pesticides (Chivinge et al, 1999). Chemical spraying of quelea birds has also killed 52 bird species (Talbort, 1997 quoted in Chivinge at al, 1999). There is evidence of increasing presence of pesticide residues in lake Manyame (Mhlanga and Madziya, 1990 in Chivinge et al, 1999) threatening the aquatic life and an urban population of about 2 million people who drink water from this lake.

Poisoning of non-target species might be easily visible and be of concern to farmers especially if these are domestic animals. If farmers are made aware of the full negative effects of pesticides on the ecosystem, this might raise their concern and prompt them to be more judicious and careful in their use of chemical pesticides. IPM farmers and NIPM farmers' awareness of the environmental hazards of chemical pesticides was assessed (Table 9).

Table 9 Farmers' awareness of effects of chemical pesticides on the environment

Effect of chemicals on environment	IPM	NIPM
	%	%
Don't know	0	8
Not harmful	0	27
Harmful	100	65
χ^2p value = 0.000		

Awareness of environmental impact of chemical pesticides is significantly associated with exposure to IPM training ($p < 0.001$). IPM farmers were more aware of the harmful effects of chemical pesticides on the environment than NIPM farmers. It is important to note that a majority of NIPM farmers (65%) and all IPM farmers were aware of the harmful effect of chemical pesticides to the environment. However about a third of NIPM believed that chemical pesticides were not harmful to the environment and about 8% did not know whether they are harmful or not.

Change in Tomato yields and input use levels

IPM farmers' tomato yields were significantly ($p<0.05$) lower than those of NIPM by about 3.9%. This is contrary to general findings in Kenya, America and Asia, where IPM was found to increase farmers' crop yields (Loevinhson et al, 1998; Weibers (1993), This could be explained by the fact that IPM farmers in Chinamora used lower quantities of fertilizer, which they substituted with compost manure.

Table 10 Farmers' tomato yields and inputs use levels

	IPM	NIPM	% Change
Yield (kg/ha season)**	8310	8650	-3.90%
Seed (kg/ha)	260	260	0
Fertilizer (Zim$/ha)**	1984	2340	-15%
Hired labor (Zim$/season)	1986	1990	-0.20%
Chemical pesticides (Zim$/ha)**	2210	5200	-57.50%

(** Difference significant at 10% significance level)

Discussions with IPM farmers revealed that it takes some time (a minimum of 3 years) for soil treated with organic material to start releasing nutrients unlike chemical fertilizers, which release nutrients instantly. This could explain why IPM farmers obtained lower yields than NIPM farmers at the time of the survey. Some research has suggested that the increase in yields of IPM farmers is probably more associated with improved cultivation practices taught in training rather than with the substitution of IPM techniques for chemicals (Duloy and Nicholas, 1991 in Weibers, 1993).

There were no significant differences on the use of seed and hired labor; both farmers spent roughly equal amount of cash on these inputs. IPM farmers used significantly lower quantities of chemical fertilizers. As expected, IPM farmers spend significantly less cash on chemical pesticide than NIPM. In fact, they reduced expenditure on chemical pesticides by about 57.5%. This finding concurs with findings elsewhere on the impact of IPM. For example Duloy and Nicholas (1991 in Weibers, 1993) found that IPM training in Bangladesh resulted in farmers reducing pesticide expenditure by 60%.

Financial returns to farmers

A partial budget assessing the net effect of the only changing elements was used to assess the net returns of IPM practices from a farmer's viewpoint. The assessment is a financial analysis and only looks at cash costs and benefits.

Table 11 Partial budget for adopting IPM practices in tomatoes (Per ha/season)

	Losses (Zim$)		**Gains (Zim$)**
Income lost	60550	**New income**	58170
8650kg x $7/kg		8310 x $7/kg	
New Costs		**Costs saved**	
Fertilizer	1984	Fertilizer	2340
Pesticides	2210	Pesticides	5200
Net gain	966		
Total	65710		65710

Notes: price of tomatoes = $7/kg

The financial gains of adopting IPM though positive are quite marginal being only $966 per ha per season. It is important however to consider that other benefits of using less harmful chemicals like savings on health cost, have not been included in the analysis.

The study findings on net returns concur with other studies on IPM. For example, in a number of studies assessing the impact of IPM conducted in the US between 1966-85, 24 showed that IPM increased net returns to farmer, while 2 found no change in net returns, and none found IPM decreasing farmers' net returns (Weibers, 1993).

IV Conclusion and recommendations

This study has revealed that PM trained farmers had significantly more knowledge and ability to identify common pests that attack tomatoes than farmers not trained in IPM principles. This knowledge of pest ecology confers farmers with higher capability to use chemical pesticides more effectively than before IPM training.

IPM trained farmers used lower quantities of pesticides and spent 57.5 % less money on chemical pesticides because they had more knowledge of non-chemical alternatives, more aware of the both the health and environmental externalities of chemical pesticides and also because they perceived lower yield loss to pest damage with zero use of chemical pesticides as compared to farmers not trained in IPM.

The analysis of this study indicated that IPM trained farmers obtained 4% lower yields than farmers not trained in IPM, though the net returns were positive due to significant savings on chemical pesticides and fertilizers. To fully understand the impacts of IPM on farmers' income and welfare it is necessary that other indirect benefits of IPM like savings on health cost be considered.

In conclusion the study findings show that IPM training has brought significant changes in farmers; perceptions, knowledge levels, pest control practices and their awareness of health and environmental externalities of chemical pesticides. In a nutshell the study shows some promising evidence that the impact of training farmers in IPM is resulting in the desired effect of discouraging heavy use of chemical pesticides, and conferring farmers with ability to use environmentally benign non-chemical options.

Given these findings, policy makers and agricultural extension services should encourage the use of a pest management strategy such as IPM that is information based. This will improve the smallholder farmers' effective use of chemical pesticides, increasing their profitability and will raise smallholder farmers' awareness of the health hazards of chemical pesticides. There is a need to also develop an IPM training and awareness program to update the knowledge and skills of field staff. For researchers, it is important that they further develop the IPM technology such that the risk of yield loss in the initial phases when farmers switch from chemical pesticide based pest management strategy to IPM is reduced.

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