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Ph.D. Thesis

Acute pesticide poisoning among Bolivian small-holder farmers - frequency, risk factors and prevention!

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It is my sincere hope that this work can be of inspiration to others when planning and conducting initiatives to prevent pesticide poisonings and pollution.

Erik Jørs, November 2015

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2. Photos of pesticide handling among Bolivian small-holder farmers
3. Photos of IPM training of farmers on Farmers Fields Schools
4. Interviewer guided questionnaire

List of abbreviations

AChE	Acetylcholineesterase enzyme
AOPEB	Asociación de Organizacion de Productores Ecologicós de Bolivia
APP	Acute pesticide poisoning
BChE	Butyrylcholinesterase
ChE	Cholinesterase
CI	Confidence interval
CIP	International Potato Center
CISU	Civil Society in Development
DANIDA	Danish International Development Aid
FFS	Farmers Field School
FG	Focus Group
FGD	Focus Group Discussion
IFAD	International Fund for Agricultural Development
IMF	International Monetary Foundation
INSO	Instituto Nacional de Salud Occupational
IPM	Integrated Pest Management
PChE	Plasmacholinesterase enzyme
PLAGBOL	Plaguicidas Bolivia
PPE	Personal protective equipment
SENASAG	Servicio Nacional de Sanidad Agropecuaria e Inocuidad Alimentaria
SChE	Serum cholinesterase

Summary

Background: Pesticide poisonings are of public concern due to the increasing pesticide use in middle- and low-income countries. In 1990, it was estimated that 3,000,000 persons were seriously poisoned by pesticides and admitted to hospitals every year of whom 200-300,000 died. These numbers could be higher today. Self-harm causes most of the serious poisonings, while occupational poisonings are far more common with an estimated 25 million annual cases in 1990.

To control pest resistance and at the same time prevent poisonings and pollution, training of farmers at Farmer Field Schools (FFS) on Integrated Pest Management (IPM) is realized. IPM includes good farming practices, reduced pesticide use, increased use of organic methods and a better personal protection when handling pesticides. Results have mainly been positive resulting in less pesticide use, higher yields, better personal protection and fewer self-reported acute pesticide poisonings (APPs). In spite of these positive results, a wider spread of IPM is still lacking.

The **overall objective** of this thesis is to estimate the prevalence of known risk factors for occupational related acute pesticide poisonings, discuss the extent of the poisonings and the role of Integrated Pest Management as a strategy in preventing such episodes among small-holder farmers in Bolivia. The data for the thesis was gathered for advocacy and evaluation purposes as part of the Plagbol development project, with the objective to prevent pesticide poisonings among Bolivian farmers.

Methods: An intervention with hands-on IPM training of farmers during two growth seasons took place from 2002 to 2004 in La Paz Department of Bolivia. The effect of this intervention was evaluated through a baseline survey carried out in 2002 before the IPM training of farmers started and two follow-up surveys from 2004 and 2009 comparing knowledge, attitude and practice regarding pesticide use and use of ecological alternatives among trained farmers (N=23) and neighboring farmers (N=47). To evaluate a possible diffusion of knowledge from trained farmer to neighboring farmer, data from the follow up survey in 2009 was compared to a control group of farmers (N=138) in a cross-sectional analysis.

A cross-sectional descriptive survey among farmers and pesticide retailers (N=231) from 2009 was carried out to describe risk factors for pesticide poisonings and the frequency of self-reported APPs.

Finally a qualitative survey with Focus Group Discussions (FGDs) among farmers and agronomists took place in 2013 (N=17), to get their opinions on obstacles and possibilities for IPM to become mainstreamed in Bolivia.

The tools for data collection throughout the research were validated interviewer guided questionnaires, observations, and FGDs. We used sound statistical analysis with a control for relevant confounders when feasible. The Medical Ethical Committee in Bolivia approved the surveys and all volunteers signed an informed consent before their participation.

Results: The cross-sectional survey among farmers and pesticide retailers documented sale and use of hazardous pesticides most often belonging to WHO class I and II. Considerable amounts of highly hazardous and obsolete pesticides were stored on the farms. The storage of pesticides was in general not safe on farms or in pesticide stores. Improper handling and inadequate use of personal protection was reported both by farmers and retailers and in less than half of the shops personal protective equipment could be purchased. The retailers knowledge on pesticide toxicity was poor, best among retailers but not significantly different from the farmers. Self-reported APPs within the last year were seen in both groups, most markedly among farmers.

IPM training of farmers significantly improved their knowledge and handling of pesticides. The use of highly hazardous pesticides and spraying frequency decreased as did the number of self-reported APPs. The changes were significant both when the performance of the trained farmers was compared to their own baseline performance and when compared to the performance of their neighboring farmers. The trained farmers showed an improvement right after the trainings stopped in 2004, and maintained their performance level when evaluated in 2009. The neighboring farmers showed an increasing improvement throughout the years but remained at a significantly lower level compared to the trained farmers.

Almost a third of the trained farmers and 13.5% of the neighboring farmers turned to organic farming.

Comparing the trained farmers and their neighboring farmers with a control group in 2009 showed poorer performance in the control group, both when compared to the trained farmers and to the neighboring farmers.

In the FGDs, farmers found IPM farming to be more laborious than conventional farming and not necessarily resulting in an increased yield or higher prices for their products. The price depended on the product as farmers growing coffee, tea, coca and strawberries found consumers willing to pay extra for organic or IPM grown products. In favor of IPM were the lower production costs, the environment-friendly and healthier IPM farming methods respecting local culture and the possibility to try out new techniques.

Discussion: The use of highly hazardous pesticides, improper storage, un-safe handling practices and frequent self-reported APPs are seen from other surveys as well. In our baseline survey from 2002, we found the risk factors for self-reported APPs and a pesticide-affected serum cholinesterase level to be the frequency of spraying and the toxicity of the pesticides used as well as the protective measures realized when handling pesticides. The frequency of self-reported APPs varied considerably between surveys which might be due to no uniform definition of a poisoning case, the use of different recall periods, the varying protective measures realized by the farmers, the different crops grown, and a varying spraying frequency and toxicity of the pesticides used.

The positive effects of IPM training on farmers' knowledge, attitude and practice regarding pesticide handling (KAP-score) and use of ecological alternatives as well as fewer self-reported APPs were seen in some other surveys as well. Most other surveys have focused on changes in farming practices and found a reduction in pesticide use and increased net revenue. In contrast to the majority of other surveys, we saw a long lasting effect on the trained farmers' KAP-score and a possible dissemination of knowledge from trained farmer to neighboring farmer. This result could be due to our emphasis on teaching farmers pedagogic methods and on how to share knowledge with their neighboring farmers.

The agreement in the FGDs on the extra workload required by IPM farming not always compensated for by higher price on the products could be important reasons for the lacking diffusion of IPM. Other reasons such as variations in patterns of pest resistance, crops grown, market access, and the quality of training are mentioned as obstacles to a spread of IPM in several papers.

A limitation of our surveys was the use of non-random sampling methods with a possibility for introducing selection bias and thereby hampering the ability to generalize our results. The community selected the farmers to go for training often being males, younger and better educated than the rest of the villagers. The neighboring farmers and control farmers were selected or invited to participate by convenience at seminars, village meetings or when found at home when the researchers came to realize the surveys in the villages. Another important limitation was the use of subjective self-reported data introducing the possibility for recall bias or information bias where the interviewed farmer says what he thinks the interviewer wants to know. The same type of biases is present in many comparable surveys, and as our results do not vary significantly from others, we think they are trustworthy although they must be interpreted with caution.

Conclusion and Recommendations: Self-reported APPs among small-holder farmers in Bolivia are common due to a widespread use of highly hazardous pesticides and improper personal protection. IPM training of farmers can improve pesticide handling, increase the use of ecological methods and reduce the number of self-reported APPs. A diffusion of IPM knowledge from trained farmers to their neighboring farmers might be a positive spin-off effect of the trainings.

Hindrances for a mainstreaming of IPM seem to be the extra workload when not compensated for by higher net revenue, although a healthier and less polluting food production is an obvious benefit of IPM farming. The frequent use and improper storage of banned and obsolete pesticides makes this a public health matter and illustrates the urgent need for effective control with pesticide imports and sales.

Political action is needed to mainstream IPM as free market forces seem to be unable to provide a solution. An effective IPM extension system and a stop to pesticide subsidies must be a political prioritization.

Future surveys should focus on evaluating different strategies to mainstream IPM such as an enforcement of extension services, diffusion from farmer to farmer and methods of awareness rising in the broader society. Not only farmers but also consumers and politicians must be able to take proper decisions to prevent pesticide poisonings and pollution.

Dansk resume

Baggrund: Pesticid forgiftninger er et betydeligt folkesundhedsproblem på grund af den stigende anvendelse af pesticider i mellem- og lavindkomstlande. I 1990 blev det anslået, at 3.000.000 blev alvorligt forgiftet af pesticider og indlagt på hospitaler hvert år, hvoraf 200-300.000 døde. Disse tal kan være højere i dag. Selvmordsforsøg er årsagen til de fleste af de alvorlige forgiftninger, mens arbejdsrelaterede forgiftninger er langt hyppigere med anslået 25 millioner årlige tilfælde.

For at forebygge pesticid resistens i skadedyr og samtidig forhindre forgiftninger og forurening promoveres uddannelse af landmænd på såkaldte Farmer Field Schools (FFS) i Integreret Pest Management (IPM). Dette omfatter en reduceret pesticidanvendelse, øget brug af økologiske metoder og bedre personlig beskyttelse ved håndtering af pesticider. Resultaterne har hovedsageligt været positive med mindre brug af pesticider, højere udbytter, bedre personlig beskyttelse og færre selvrapporterede forgiftninger til følge, men en 'main-streaming' af IPM i landbruget er ikke sket.

Det overordnede formål med denne afhandling er at estimere hyppigheden af kendte risikofaktorer for arbejdsrelaterede akutte pesticid forgiftninger, diskutere omfanget af forgiftninger og den rolle Integreret Pest Management som kan spille om en strategi for at forebygge forgiftninger blandt småbønder i Bolivia. Data blev indsamlet som en del af udviklingsprojektet Plagbol, der arbejder med at forebygge pesticidforgiftninger.

Metode: En intervention med hands-on IPM træning af landmænd fandt sted over to vækstsæsoner fra 2002 til 2004 i La Paz Department i Bolivia. Effekten af denne indsats blev evalueret gennem en baseline undersøgelse foretaget i 2002, før IPM uddannelse af landbrugere gik i gang, og to follow-up undersøgelser fra 2004 og 2009. Undersøgelserne sammenligner viden, holdning og praksis vedrørende brug og anvendelse af økologiske alternativer pesticider blandt IPM trænede landmænd (N=23) og nabolandmænd (N=47). For at vurdere en mulig spredning af IPM viden fra uddannet landmand til nabolandmænd blev data fra follow-up undersøgelsen i 2009 sammenlignet med en kontrolgruppe af landmænd (N = 138) i en tværsnitsanalyse.

En tværsnitsundersøgelse blandt landmænd og pesticid forhandlere (N = 231) blev gennemført i 2009 for at beskrive risikofaktorer for pesticid forgiftninger og hyppigheden af selvrapporterede forgiftninger.

Endelig gennemførtes en kvalitativ undersøgelse med fokusgruppediskussioner (FGDs) blandt landmænd og agronomer i 2013 (N=17), for at høre deres mening om forhindringer og muligheder for IPM's udbredelse i landbruget i Bolivia.

Til dataindsamling blev brugt validerede interviewer guidede spørgeskemaer, observationer og fokusgruppediskussioner. Vi brugte simpel statistisk analyse med kontrol for mulige fejlkilder hvor muligt. Medicinsk Etisk Udvalg i Bolivia godkendte undersøgelserne og alle frivillige underskrev et informeret samtykke, før deres deltagelse.

Resultater: Tværsnitsundersøgelsen blandt landmænd og pesticidforhandlere viste et salg og forbrug af farlige pesticider oftest tilhørende WHO klasse I og II. Betydelige mængder af meget farlige og forældede pesticider blev opbevaret på gårdene. Opbevaring af pesticider var i de fleste tilfælde ikke sikre hverken på gårdene eller i butikkerne.

Forkert håndtering og utilstrækkelig brug af personlige værnemidler blev rapporteret af både landmænd og detailhandlere, og i mindre end halvdelen af butikkerne kunne købes personlige værnemidler. Viden om pesticiders giftmærkning var dårlig, bedst blandt forhandlerne men uden signifikant forskel fra landmændene. Selvoplevede forgiftningstilfælde inden for det sidste år blev påvist i begge grupper, mest markant blandt landmænd.

IPM uddannelse af landbrugere forbedrede i høj grad deres viden om og håndtering af pesticider. Brugen af de yderst farlige pesticider og sprøjtehyppigheden faldt ligesom antallet af selvoplevede forgiftninger faldt. Forbedringer blev også set blandt de nabolandmænd om end i mindre grad. De trænede landmænd viste en stor forbedring lige efter deres træningsperiodeblev afsluttet i 2004, og fastholdt deres niveau da de blev evalueret i 2009. Nabolandmændene viste en jævnt stigende forbedring af viden og praksis gennem årene. Næsten en tredjedel af de trænede landmænd gik over til økologisk landbrug, noget som også sås blandt 13,5% af nabolandmændene.

Ved at sammenligne de trænede landmænd og nabolandmænd med en kontrolgruppe af landmænd udenfor projektområdet i 2009 påvistes dårligere præstationer i kontrolgruppen, både i forhold til de uddannede landmænd og til nabolandmænd.

I fokusgruppe diskussioner fandt landmænd og agronomer at IPM landbrug var mere arbejdskrævende end konventionelt landbrug og ikke nødvendigvis resulterede i et forøget udbytte eller højere priser på produkterne. Prisen afhang af produktet, idet landmænd der dyrkede kaffe, te, coca og jordbær fandt forbrugerne villige til at betale ekstra for økologiske eller IPM dyrkede produkter. Til fordel for IPM var de lavere produktionsomkostninger, miljøvenlige og sundere IPM dyrkningsmetoder med respekt for den lokale kultur og muligheden for at afprøve nye teknikker.

Diskussion: Brugen af meget farlige pesticider, lemfældig opbevaring, og farlig håndtering medførte hyppige selvrapporterede forgiftninger, hvilket også er set i andre lignende undersøgelser. I vores baseline undersøgelse fra 2002 fandt vi risikofaktorerne for selvoplevede forgiftninger og et pesticid påvirket serumcholinesterase niveau til at være hyppigheden og toksiciteten af de anvendte pesticider, samt beskyttelsesforanstaltninger ved håndtering af pesticider. Hyppigheden af selvrapporterede forgiftninger varierede betydeligt mellem undersøgelserne på grund af uensartet definition af en forgiftning, brug af forskellige rapporterings perioder, varierende beskyttelsesforanstaltninger blandt landmændene, forskellige afgrøder og en varierende sprøjtning frekvens og giftighed af de anvendte pesticider.

De positive effekter af IPM uddannelse sås på viden, holdning og praksis ved pesticidhåndtering (udtrykt som en samlet KAP-score), øget brug af økologiske alternativer samt færre selvrapporterede forgiftninger som også rapporteret fra andre undersøgelser. De fleste undersøgelser har dog fokuseret mest på ændringer i landbrugspraksis og fandt en reduktion i anvendelsen af pesticider og en øget nettoomsætning.

I modsætning til de fleste andre undersøgelser på området, så vi en langvarig effekt blandt trænede landmænd, og en mulig spredning af viden fra uddannet landmand til nabolandmand. Dette kan bl.a. skyldes vores fokus på at undervise landmænd i pædagogiske metoder, og vidensdeling med nabolandmænd.

Den ekstra arbejdsbyrde der kræves af IPM landbrug og som ikke altid kompenseres ved en højere pris på produkterne kan være en vigtig årsag til den manglende udbredelse af IPM. Andre årsager såsom variationer i mønstre af skadedyr modstand, dyrkede afgrøder, markedsadgang, og kvaliteten af uddannelsen er nævnt som en hindring for spredning af IPM i flere studier.

En svaghed ved vore undersøgelser var brugen af ikke-tilfældig udvælgelse af deltagerne, hvilket gav mulighed for selektionsbias. Dette hæmmer muligheden for at generalisere vores resultater. Landsbybeboerne valgte selv bønderne der skulle på kursus, og det var ofte mænd, der var yngre og bedre uddannede end resten af landsbybeboerne. Nabolandmænd og kontrol landmænd blev opfordret til frivillig deltagelse på seminarer, landsbymøder eller når fundet hjemme, når forskerne kom for at gennemføre et vist antal undersøgelser i deres landsbyer.

En anden vigtig begrænsning var brugen af subjektive selvrapporterede data, hvor den interviewede kan huske forkert eller fortælle det som han forventer intervieweren gerne vil høre. De samme typer af bias er til stede i mange sammenlignelige undersøgelser, og da vores resultater ikke varierer væsentligt fra andre, tror vi, at de er troværdige, selv om de skal tolkes med forsigtighed.

Konklusion og anbefalinger: Selvrapporterede forgiftninger blandt landmænd i Bolivia ses hyppigt på grund af en udbredt brug af meget giftige pesticider og en utilstrækkelig personlig beskyttelse. IPM uddannelse af landbrugere kan forbedre håndteringen af pesticider, øge brugen af økologiske metoder og reducere antallet af selvrapporterede forgiftninger. En udbredelse af IPM viden fra uddannede landmænd til deres nabolandmænd kan være en positiv spin-off effekt.

Hindringer for en udbredelse af IPM synes at være den ekstra arbejdsbyrde, når den ikke opvejes af højere nettoindtjening, selv om en sundere og mindre forurenende fødevareproduktion er en indlysende fordel ved IPM landbrug. Den hyppige brug og forkerte opbevaring af forbudte og forældede pesticider gør dette til en folkesundheds problem, og illustrerer det påtrængende behov for effektiv kontrol med import og salg af pesticider.

Der er behov for politisk handling for at 'main-streame' IPM da de frie markedskræfter synes at være ude af stand til at levere en løsning. En effektivt IPM rådgivning til landmænd og et stop for subsidier til pesticider bør være en politisk prioritet.

Fremtidige undersøgelser bør fokusere på at vurdere forskellige strategier til at integrere IPM såsom en udbygning af konsulenttjenester, diffusion af viden fra landmand til landmand og metoder til at øge viden i det omgivende samfund som helhed. Ikke blot landmænd, men også forbrugere og politikere skal kunne træffe korrekte beslutninger for at forhindre pesticid-forgiftning og forurening.

List of papers included in the thesis

1. Haj-Younes J, Huici O, Jørs E. **Sale, storage and use of legal, illegal and obsolete pesticides in Bolivia.** Cogent Food & Agriculture 2015 doi.org/10.1080/23311932.2015.1008860

2. Jørs E, Lander F, Huici O, Morant RC, Gulis G, Konradsen F. **Do Bolivian small-holder farmers improve and retain knowledge to reduce occupational pesticide poisonings after training on Integrated Pest Management?** Environ Health. 2014; doi:10.1186/1476-069X-13-75

3. Jørs E, Konradsen F, Huici O, Morant CR, Volk J, Lander F. **Impact of training Bolivian farmers on Integrated Pest Management and diffusion of knowledge to neighboring farmers.** Accepted for publishing in Journal of Agromedicine. In press.

4. Jørs E, Aramayo A, Omar H, Konradsen F, Gulis G. **Obstacles and possibilities for diffusion of Integrated Pest Management strategies among Bolivian farmers to control negative consequences of inadequate pesticide use!**
Submitted to Journal of Agromedicine. In review.

Chapter 1

Background

1.1 Introduction

The basis of the present thesis represents experiences gathered during the Plagbol development project, a project aiming at preventing acute pesticide poisonings (APP) among small-holder farmers in Bolivia.

Frequent occupational pesticide poisonings among farmers were documented in a survey performed by the National Institute of Occupational Health in Bolivia in 1989 and a wish to take preventive measures was expressed (1). To address this concern the Plagbol project supported by Danish International Development Assistance was carried out from 2001 to 2013. The intervention consisted among others in training of small-holder farmers on Integrated Pest Management (IPM) (2).

IPM is a strategy to prevent pest resistance by lowering or replacing pesticide use with organic methods, and thereby at the same time preventing occupational pesticide poisonings (3-5).

As part of the project activities, data was collected to evaluate the amount and type of pesticides used by the farmers, the risk factors for poisonings, the frequency of poisonings and the effect of training farmers on IPM. These surveys supported the project advocacy and awareness rising activities, through the elaborating of teaching and informative materials, radio and television programs. As the Danish coordinator, the PhD student has participated in planning and supervision of project activities together with the Bolivian project staff and Danish colleagues.

This thesis evaluates the frequency of APPs among Bolivian small-holder farmers, the risk factors for an APP and the possibilities for prevention. The thesis will add to the outcome of the Plagbol project and be used for awareness rising and advocacy purposes in Bolivia and other countries.

The core of the thesis is the surveys presented in the four papers in the chapters 5-7. Chapter 4 on Methods and chapter 8 on Discussion are summaries of the content in the papers. The Discussion in chapter 8 focuses on the conflictive or puzzling findings from our own surveys and in surveys by others. In chapter 9 we conclude on the main findings and give our recommendations for future surveys and actions to prevent APPs among small-holder farmers in Bolivia and elsewhere.

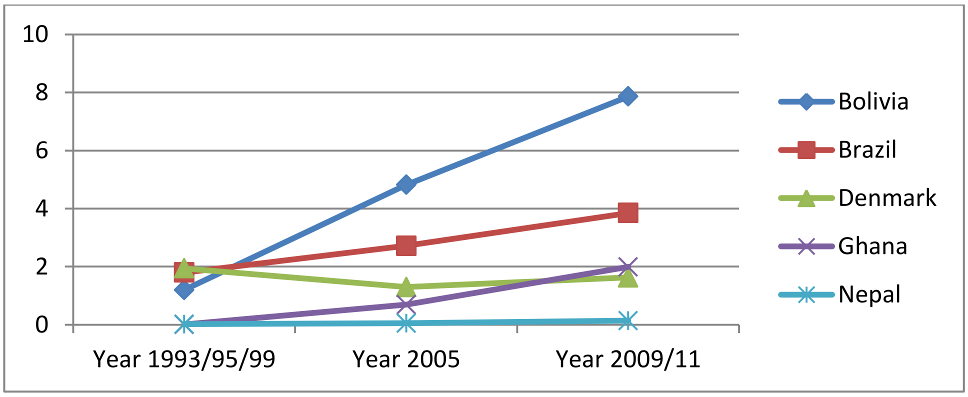
1.2 Global pesticide use

Pesticides are toxic chemicals meant to control pests like insects, fungus, bacteria and weeds (6, 7). At the same time they are toxic to other living species including humans (6, 7). More than 80% of the global pesticide consumption is used in farming to protect seeds, crops and products as some kind of pest control is necessary to avoid losses of 50% or more (8). The remaining amounts of pesticides are used in public health vector programs, in private homes and other places (7-10).

The use of pesticides has grown steadily and has now reached 3.5 billion kg of active ingredient per year of which 70% is used by China, Argentina and USA (10, 11). Globally the average use is 3.2 kg of active ingredients per ha of crop, but this vary a lot. Farmers in high- and higher-middle-income countries use more than farmers from lower-middle and low-income countries both in total amounts and in amounts to be able to reach the same yield per ha (10, 11). The increase in pesticide use over the past 20 years has been highest in low-income countries starting from a low base like Cameroon, Ethiopia and Burkina Faso with an 8 to 50 fold increase (10). Middle-income countries like China, Argentina, Brazil and Thailand have increased from 3 to 8 fold while the use has been stable or even decreasing in high-income countries like in USA, Germany, Japan and Denmark (10).

Fig 1 illustrates the increase in use of pesticides in a few selected countries (12).

Fig 1 – Development in pesticide consumption (kg of active ingredient per hectare cropland)



Source FAOSTAT, data retrieved on the 1/10-2015

The eightfold increase in amounts of pesticides used in Bolivia reflects both an initial low level of pesticide use and a doubling of hectares of cultivated land since 1995 in the tropics of Bolivia (12, 13).

The overall picture seems to be an increasing pesticide use in many middle- and low-income countries trying to boost their agriculture without much environmental or health concerns, while high-income countries like Denmark try to minimize their use turning to IPM and organic farming methods to avoid increasing the already existing pollution of the environment and control long term negative health effects (10, 11, 14).

1.3 Pesticide classification

Pesticides can be classified according to their target organisms, chemical class, and toxicity. Pesticides are divided into insecticides, fungicides, herbicides, rodenticides and bactericides (15). Herbicides are by far the most used pesticides in agriculture to avoid the workload of weeding at global level, but among many small-holder farmers in low-income countries like Bolivia insecticides are the most used, as weeding to a greater extent is done manually (7, 12, 14, 16, 17).

The most common chemical classes are organophosphates, organochlorides, carbamates, pyrethroides and dipyridils (15). In the forties and fifties organochlorides were the most used insecticides in agriculture and vector programs but they have later been restricted for use or banned in most countries due to their persistency in the environment. Many of them are classified as Persistent Organic Pollutants forming part of the so called ‘dirty dozen’ (14, 18-20).

Along with the organochlorides the organophosphates and later the carbamates and dipyridils were introduced, being more acute toxic to humans than the organochlorines but not as persistent in the environment (6). Pyrethroides are not found to be very toxic to humans, although long-term negative health effects might be expected from these pesticides as well (6, 21).

In the past decade a new class of pesticides named nicotinoides have entered the market being less toxic to humans (22).

WHO has made a classification dividing pesticides into the toxicity classes Ia, Ib, II, III, U with falling toxicity and O being the sign for obsolete pesticides, see table 1 (23). Obsolete pesticides are defined as those pesticides that can no longer be used for their intended purpose or wanted to be used and therefore must be disposed of. They include among others banned, outdated and deteriorated pesticides (18).

Table 1 WHO classification of the toxicity of pesticides

WHO class	Classification	LD 50 for the rat (mg/kg b.w.)	
		Oral	**Dermal**
Ia	Extremely hazardous	Less than 5	Less than 50
Ib	Highly hazardous	50-50	50-200
II	Moderately hazardous	50-2000	200-2000
III	Slightly hazardous	Above 2000	Above 2000
U	Unlike to present acute hazard	Above 5000	Above 5000

While the most toxic pesticides belonging to WHO class Ia and Ib, and some pesticides belonging to class II and class O have been restricted for use or banned in many countries, they are still widely used in middle- and low-income countries due to their effectivity in killing pests of a broad spectrum and often being cheaper and simpler to produce and use (7, 14, 18). FAO estimates that half a million tons of obsolete pesticides are scattered throughout the developing world, often stored outdoors in leaking containers seeping into the soil and water (18).

1.4 Acute pesticide poisonings (APP) – definition and symptoms

An APP is defined as any illness or health effect resulting within 48 hours after a suspected or confirmed exposure to a pesticide, with the exception of the anticoagulation pesticides (24, 25). Health effects may be local affecting the skin or eyes and/or systemic including respiratory, neurotoxic, cardiovascular, endocrine, gastrointestinal, nephrotoxic and allergic reactions (24, 26, 27).

Pesticides are entering the human body through the skin, airways and digestive tract (26, 27). Most pesticides are toxic to the nervous system like the organophosphates, carbamates, organochlorides and pyrethroides all interfering with the activity of the nerve cells leading to hyper- or hypo-activity (26). Insecticides are the most toxic class of pesticides, and a study showed that 80% of the poisoning cases were caused by insecticides (28).

Symptoms of acute poisoning depend on the class of pesticide as seen from table 2 presenting common pesticide classes and symptoms of poisoning (24).

Table 2 Classes of pesticides and symptoms of pesticide poisonings

Chemical class	Use	WHO class*	Symptoms of acute poisoning
Organochlorides Aldrin, dieldrin, lindane, DDT	Insecticide	Ib, II, O	Cyanosis, excitability, dizziness, headache, restlessness, tremors, convulsions, coma, paresthesias, nausea, vomiting, confusion, tremor, cardiac arrhythmias, acidosis
Organophosphates Malathion,parathion metamidophos, mono-crotophos, chlorpyrifos, propenofos, dimethoate	Insecticide	Ia, Ib, II,III	Headache, dizziness, bradycardia, weakness, anxiety, excessive sweating, fasciculations, vomiting, diarrhoea, abdominal cramps, dyspnea, miosis, paralysis, salivation, tearing, ataxia, pulmonary oedema, confusion, acetylcholinesterase inhibition
Carbamates Carbaryl, thiram, aldicarb, mecarbam	Insecticide	Ia, II	Malaise, weakness, dizziness, sweating, headache, salivation, nausea, vomiting, diarrhoea, abdominal pain, confusion, dyspnea, dermatitis, pulmonary oedema
Pyrethroids Cyflothrin, permethrin, cypermethrin, deltamethrin	Insecticide	Ib, II	Allergic reactions, anaphylaxis, dermatitis, paresthesias, wheezing, seizures, coma, pulmonary oedema, diarrhoea, abdominal pain
Phosphonates Glyphosate	Herbicide	III	Airway, skin, and mucous membrane irritation, abdominal, pain, nausea, vomiting, shock, dyspnea, respiratory failure
Dipyridil Paraquat Diquat	Herbicide	II	Mucous membrane and airway irritation, abdominal pain, diarrhoea, vomiting, gastrointestinal bleeding, pulmonary oedema and fibrosis, dermatitis, renal and hepatic damage, acute respiratory distress syndrome, coma, seizures
Organotin Fentin acetate, fentin chloride	Fungicide	II, NL**	Airway, skin, and mucous membrane irritation, dermatitis, salivation, delirium, headache, vomiting, dizziness
Coumarins Brodifacoum, warfarin, pindone	Rodenticide	Ia, Ib	Echymoses, epistaxis, excessive bleeding, haematuria, prolonged prothrombin time, intracranial bleed, anaemia, fatigue, dyspnea

***=toxicity class of mentioned pesticides, see Pesticide Properties DataBase University of Herforshire**
www.sitem.herts.ac.uk/aeru/ppdb/en/index.htm
**** NL=not listed**

Chronic health effects can be caused by a single acute poisoning, several acute poisonings or sub-acute chronic poisonings. Chronic health effects can be allergies, neurotoxic disease, psychiatric disease, respiratory disease, reprotoxic damage, fetotoxic damage and cancer, all being related to different pesticides or mixtures of pesticides (21, 29-34).

1.5 Frequency of acute pesticide poisonings

In 1990, WHO estimated an annual number of 3,000,000 hospitalized APPs worldwide and 220,000 fatalities. Seven-hundred thousands of the severe poisonings were classified as occupational and 300.000 as accidental while two million were intentional (35). It was estimated that 99% of these incidents took place in low-income countries using 20% of the world's pesticides (35). It was assumed that there might be as many as 25 million agricultural workers in low-income countries suffering from less serious occupational poisoning each year, based on estimates from surveys in Asia (35).

These estimates have proven to be pretty robust but the real magnitude of the problem is still unknown. This is due to insufficient registers of poisonings in most countries and a lack of a uniform definition of an APP (24, 36).

In 2007, the global number of deaths due to self-poisoning with pesticide was estimated to be 258,234 (range 233,997 to 325,907) arising from 1,291,170 to 2,582,340 episodes of pesticide self-poisoning annually (37).

The frequencies of occupational pesticide poisonings found in surveys among farmers using mainly knapsack sprayers are seen in table 3. Knapsack sprayers are the devices for spreading pesticides used among the majority of small-holder farmers in middle- and low-income countries (see photos annex 1).

In most of the surveys an APP is defined as one or more self-reported symptoms of poisoning in connection with pesticide handling. The lowest estimate is a 12-month period prevalence of 7% for ‘cases of poisoning needing medical assistance’ and the highest estimate is a lifetime prevalence of 93% among farmers having experienced ‘one or more symptoms of poisoning after pesticide handling during their life’.

The importance of a uniform case definition is illustrated in the survey during a cropping season from India, where 83.6% of the 323 spraying sessions reported was followed by at least one symptom of poisoning, while 10% was followed by 3 or more symptoms (16). Among these APPs 39% was classified as a mild poisoning, 38 % as a moderate poisoning and 6% as a severe poisoning (16).

A global survey including 6359 small-holders from 24 countries reported a mean 12-month period prevalence of 6.4% among farmers and spray-men requiring medical assistance after spraying and 19.8% reporting minor incidents, but with huge differences among countries varying from 0% in Brazil to 85.2% in Morocco (28).

The degree of exposure to organophosphates or carbamates and the new chlorinated derivatives of nicotine can be measured by a depression of the biomarkers acetylcholinesterase (AChE = red blood cell ChE) or butyrylcholinesterase (BChE or PChE = plasma ChE) (38, 39). AChE is useful in evaluating long-term exposure to pesticides, while PChE is more useful for detecting acute pesticide exposure as the half-life of PChE is found to be days to weeks and for AChE weeks to months (38-40).

From table 3 different reductions in ChE (including both AChE and BChE/PChE) can be seen where a 30% depression or more from non-spraying season to spraying season is common. Cross-sectional surveys including a control group found Odds Ratios for symptoms and a depressed ChE to be elevated to varying degrees among pesticide-exposed farmers (41-43).

Along with the increasing pesticide use in middle- and low-income countries an increase in the number of APPs can be expected. A survey from Central America showed an increasing incidence of APPs from 6.3 to 19.5 per 100,000 population from 1992 to 2000, while a more recent survey from India showed an increasing incidence of 1.19 to 2.03 per 1000 population from 2008 to 2013(36, 44). In both countries pesticide use did increase considerably during the study periods (12, 36, 44). In a high-income country like Korea where the pesticide use is decreasing, the numbers of APPs are declining as well, with the average annual death rate decreasing from 5.74 to 4.85 per 100,000 population from 2006 to 2010 (45).

Table 3: Frequency and risk factors of APP and a lowered Cholinesterase-level among agricultural workers handling mainly knapsack sprayers

Ref. no.	Author, publishing year, country and income level	Methods, number of participants and sampling *	Self-reported symptoms and observed signs of APP among farmers	Affection of cholinesterase enzyme activity in blood	Personal protection as a risk factor for APP **	Pesticide exposure as a risk factor for APP ***
			Follow-up studies			
(46)	Pasiani, 2012 Brazil, Middle-income	Interviews, blood tests 112 tomato/sweet pepper farmers, 64 controls Non-random sampling	23.2% 'lifetime prevalence' ≥1 symptom	ChE lower among farmers in spraying period compared to controls and compared to own values from non-exposure periods 16.7% of farmers had >30% depletion in spraying periods compared to non-spraying period	No influence	No influence
(47)	Khan, 2010 Pakistan, Middle-income	Interviews, observations, blood tests 105 tobacco farmers Random sampling		33 % mild poisoning = PChE> 20-40% reduced 11 % moderate poisoning = PChE> 40% reduced compared to non-spraying period	PChE improves with more protective measures	
(16)	Mancini, 2005 India, Middle-income	Interviews 97 cotton farmers Non-random sampling	83.6% of 323 spraying sessions ≥1 symptom (39% mild, 38% moderate, 6% serious) 10% of the spraying sessions followed by ≥3 symptoms	.		Symptoms decreases with less exposure
(48)	Smit, 2003 Sri Lanka Low-income	Interviews, blood tests 122 IPM farmers/94 general farmers/44 controls Vegetable farmers, fishermen Random sampling	24% life-time prevalence among farmers, 16.2% of all farmers received medical treatment for APP at one point in time	AChE lower among pesticide exposed farmers during spraying season compared to controls Mean inhibition 8% among IPM farmers, 10.5% among general farmers, 3.2% among controls)		AChE improves in low-exposure periods
(49)	Murphy, 2002 Vietnam, Middle-income	Interviews, self-reports 50 farmers reporting symptom after spraying 50 control farmers Random sampling	92% out of 1798 spraying operations was followed by mild to moderate symptoms (average no. 3.9) and 31% by ≥ 1 clear symptom of APP among self-reporting farmers			After 6 months the use of Class Ia+b pesticides declined along with symptoms among farmers included to report symptoms after every spraying vs the

						controls
(50)	Ohayo-Mitoko 2000, Kenya Middle-income	Interviews and blood tests 623 farmers, 515 controls Random sampling	40.1% 'lifetime prevalence' among farmers having ≥1 symptom of which 25.4% sought medical treatment	AChE lower among exposed farmers vs controls (4.17 IU/ml-6.02 IU/ml) 41% of farmers had ≥30% AChE inhibition from low to high exposure period		Symptoms among farmers was higher in high exposure period, while at the same level as controls in low-exposure period
(51)	Kishi, 1995 Indonesia Middle-income	Interviews, observations 204 rice and vegetable farmers and 24 prof sprayers Non-random sampling	21% of 906 spraying sessions were followed by ≥3 symptoms		Farmers with high skin exposure had more symptoms	Symptoms decreased in low exposure period
			<u>Cross-sectional studies</u>			
(52)	Lekei, 2014 Tanzania, Low-income	Interviews 121 coffee/vegetable farmers Non-random sampling	93% 'lifetime prevalence' ≥1 symptom, 21% of farmers with APP attended hospital		Symptoms were marginally associated with risky behaviors	.
(41)	Neupane, 2014 Nepal, Low-income	Interviews and blood tests 90 vegetable farmers, 90 controls, Random sampling	Up to 50 % 'one month prevalence' and elevated OR for possible APP symptoms among farmers (1.77 - 7.25) compared to controls	AChE lower among farmers compared to controls		
(53)	Kim, 2013 Korea, High-income	Interviews 1958 rice/vegetable/fruit farmers Random sampling	22.9 % '12 months prevalence' ≥1 symptom of an APP		OR varied from 1.24-1.61 for an APP for 6 out of 13 unsafe behaviors	OR 1.49-1.74 for symptoms if more application days and farm size ≥3 acres
(54)	Lee, 2012 Korea, High-income	Interviews 1958 rice/vegetable/fruit farmers Random sampling	One year incidence was 8.6% of moderate to severe APPs 2.7% got medical treatment			
(55)	Jensen, 2011 Cambodia, Low-income	Interviews 89 vegetable farmers Non-random sampling	88% 'one month prevalence' ≥1 symptom of an APP		High educated farmers reduced their risk for an APP with 50% by each protective measure adapted	Each extra hour spraying increased the risk of an APP with 14%
(56)	Zhang , 2011 China,	Interviews 910 farmers	8.8 % '12 months prevalence' ≥2 symptoms of an APP		OR increased (0-9.73) for symptoms	

	Middle-income	Non-random sampling			with more risky behavior	
(57)	Kachaiyaphum 2010, Thailand, Middle-income	Interviews, blood tests 350 chili farmers Random sampling		32 % 'point prevalence' abnormal SChE defined as <87.5 U/ml	OR was 5.4 for of an APP if poor personal protection	OR was 6.3 for an abnormal SChE if >3 times pesticide use/month
(28)	Tomenson, 2009, Twenty-four countries	Interviews 6359 knapsack using farmers, mainly from low and medium income countries, but including 4 from Europe Non-random sampling	6.4 % '12 months prevalence' of serious to moderate APPs in the need for medical assistance 19.8 % '12 months prevalence' of minor symptoms of APP Highest prevalence in middle- and low- income countries		Increased OR (1.53) for moderate APP with leaking sprayer, and decreased OR (0.56-0.7) for confidence in PPE and good hygiene	
(58)	Cataño, 2008 Peru, Middle income	Interviews, blood tests 213 agricultural workers/78 controls Non-random sampling	61 % 'lifetime prevalence' with ≥1 symptom of an APP 15.2 % needed medical treatment for an APP	PChE lower among agricultural workers compared to controls	,OR was lower (0.46) for symptoms of APP and PChE higher among those using PPE	PChE lower among those working more years with pesticides
(59)	Dasgupta, 2007 Vietnam, Middle-income	Interviews, blood tests 190 rice farmers, selected on the basis of a questionnaire Non-random sampling	88% point prevalence of self-reported APP with a mean of 4 symptoms most prevalent being skin irritation 66%, headache 61%, dizziness 49%, eye irritation 56% and breathlessness 44%	AChE depression 25-66% among 14% of farmers and >66 % among 21 % of farmers	AChE lowered if <3 PPE used Probability of poisoning falls by 44% with more protective measures used	AChE lowered by use of WHO class I pesticides (1% increase in use increases probability of APP with 3.9%)
(60)	Jørs, 2006 Bolivia Middle-income	Interviews, blood tests 171 male vegetable and fruit farmers Non-random sampling	70% one year prevalence and 45% one month prevalence of self-reported APP with ≥1 symptom		OR for APP decreases with increasing number of precautions performed ChE was higher among farmers reading pesticide	ChE activity was 8.36 kU/L among non-sprayers, 7,60 for spraying 1-3 times and 7.12 for spraying > 3 times past month. ChE activity was 7.11 kU/L versus 8.03 for

				labels (7.46 versus 6.84 kU/L)	spraying OPs or not. OR for self-reported APP increased with increasing pesticide exposure past month
(61)	Nordin, 2002 Indonesia, Middle-income	Interviews 496 tobacco farmers Random sampling	76 % ’6 month prevalence’ ≥1 symptom of an APP	Symptoms lowered if no smoking while spraying, using sprayer in good condition and changing clothes after spraying	
(62)	Yassin, 2002 Gaza Middle-income	Interviews 185 vegetable/fruit farmers Random sampling	83.2 % ’3 month prevalence’ ≥1 symptom of an APP	Symptoms increases with lower re-entry period	Symptoms increases with higher amounts used and if mixing pesticides

*Random sampling indicated if stated in article, otherwise non-random sampling is indicate, ** Personal protection includes protective equipment (PPE) and hygiene (use of boots, mask, gloves, long pants, long sleeved shirt, hat, overall, bathing after spraying, changing and/or washing clothes after spraying, no smoking or eating while spraying a.o.). *** Lower exposure level refers to a lowered spraying intensity and/or less pesticide toxicity and/or fewer years of spraying.

Abbreviations: AChE=acethylcholineesterase, PChE=plasma or serumcholineesterase, PPE=personal protective equipment, APP=acute pesticide poisoning, OPs=organophosphates

1.6 Risk factors for pesticide poisonings among farmers

Known risk factors for occupational APPs are the magnitude of exposure depending on the toxicity of the pesticides used and the intensity of spraying as seen from table 3. WHO and FAO estimate that 30% of the marketed pesticides in low-income countries do not conform to international safety and quality standards and that one third of the pesticides comes from illegal import or sale from stockpiles of thousands of tons of obsolete and extremely or highly hazardous pesticides (7, 25, 63).

Little knowledge on pesticide dangers leads to inadequate use of protective devices and insufficient hygiene when handling pesticides, other factors shown to be of importance for APPs as seen from table 3.

A problem is the low educational level as farmers often cannot read the instructions on the pesticide container to get information on safety measures and pesticide toxicity, and sometimes the instructions are written in a foreign language further aggravating the situation (16, 47, 64-66).

A dangerous habit of blowing or sucking the spray-head when obstructed instead of rinsing the spray-head with water or shifting to a new spray-head varied from being used by 2% to 49% of the farmers in surveys from different countries (17, 55, 60).

The use of personal protective devices and hygiene varies a lot as seen from table 4. Farmers in lower-middle and low-income countries seem to use less protective measures especially boots, gloves and masks than farmers from high- and higher-middle-income countries. This can be due to lack of knowledge of pesticide dangers (67, 68), hot climate making PPE uncomfortable to wear (62, 68-70), the PPE being too expensive to purchase for resource-poor farmers or being unavailable in pesticide stores in the villages (62, 65).

Leaking knapsack sprayers are reported by 51% of farmers in a global survey increasing the risks for poisoning through skin absorption and clothes contaminated by pesticides (51, 65).

Table 4: Prevalence of personal protective measures used by knapsack spraying farmers when handling pesticides

Ref. no.	Author, publishing year, country, study population	Reads instruction for use	Uses long sleeved shirt	Uses long pants	Uses hat	Uses boots (shoes)	Uses gloves	Uses mask or face scarf	Does not eat and/or smoke while spraying	Washes body after spraying	Changes clothes after spraying
Global											
(65)	Matthews, 2008, 26 countries 8500 farmers		82 %	82 %		54 %	50 %	29 %	>72 %		
High-income countries											
(53)	Kim J-H, 2013, Korea 1958 male farmworkers	86 %		59 %	83 %	85 %	51 %	47 %		94 %	94 %
Higher-middle income countries											
(42)	Sapbamrer, 2013, Thailand 63 farmers	89 %	97 %	95 %	95 %	97 %	92 %	89 %	91 %	97 %	94 %
(46)	Pasiani, 2012, Brazil 112 vegetable farmers	69 %			70 %	79 %	57 %	72 %			
(71)	Naidoo S, 2010, South Africa 366 female farmworkers	19 %				44 %	18 %	13 %			
(57)	Kachaiyaphum, 2010, Thailand 350 farmers	70 %	87 %	87 %	68 %	67 %	19 %	67 %	89 %	51 %	
(72)	Hurtig AK, 2003, Ecuador 111farmworkers		56 %	93 %	71 %	99 %	5 %	7 %	58 %	89 %	76 %
(61)	Nordin RB, 2002, Malaysia 496 farmworkers		99 %	96 %	93 %	67 %	67 %	54 %	98 %	98 %	71 %
Lower-middle income countries											
(47)	Khan AD, 2010, Pakistan 105 Tobacco farmers					30 %	9 %	15 %		88 %	93 %
(59)	Dasgupta S, 2007, Vietnam 190 rice farmers				49 %	2 %	18 %	61 %			
(60)	Jørs E, 2006, Bolivia 171 vegetable and fruit farmers	74 %				16 %	16 %	17 %	15%	54 %	47 %
(62)	Yassin MM, 2002, Palestine 189 farmworkers				12 %	15 %	20 %	22 %	>82 %	54 %	

	Low-income countries										
(66)	Okonya JS, 2015, Uganda 204 potato farmers		42 %			73 %	7 %	16 %			
(52)	Lekei EE, 2014, Tanzania 121 coffee and vegetable farmers	71 %			<10 %	38 %	<10 %	<10 %			
(41)	Neupane D, 2014, Nepal 90 rice and vegetable farmers		56 %	33 %	64 %	<10 %	<10 %	46 %	72 %	70 %	84 %
(17)	Østerlund AH, 2012, Uganda 317 vegetable and cotton farmers	74 %	24 %	8 %	8 %	51 %	12 %				
(55)	Jensen HK, 2010, Cambodia 89 vegetable farmers	46 %	85 %	87 %	93 %	3 %	18 %	49 %	88 %	98 %	96 %
(48)	Smit, 2003 , Sri Lanka, 216 vegetable farmers		86 %	94 %	69 %	<0.5%	3 %	9 %	>66%		

1.7 Prevention of pesticide poisonings by training farmers on Integrated Pest Management

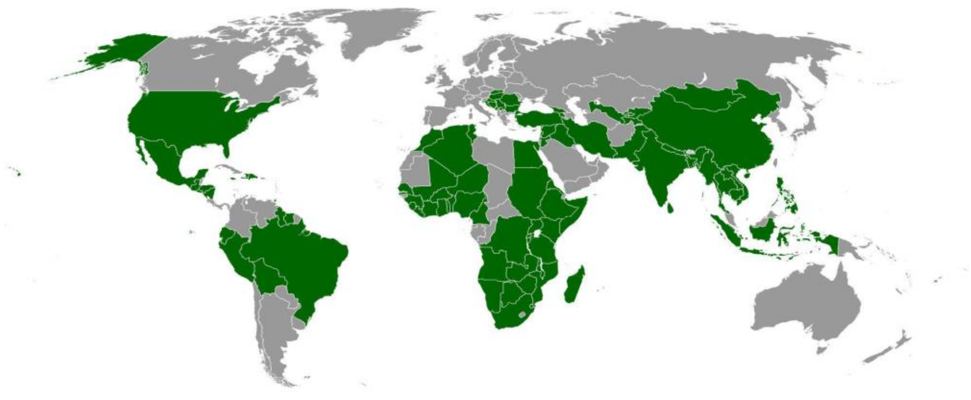
IPM is promoted by FAO and others to tackle pest resistance to pesticides and pollution by the introduction of organic alternative to pesticides and good farming practices (3-5, 14, 73, 74). A secondary gain by reducing amounts of pesticides used and thereby farmers' exposure is a reduction in the number of occupational APPs (3-5, 73, 74).

IPM was initially developed in the 1960's and from the late 1980's it became implemented in Indonesia suffering serious pest resistance in rice crop. Later it was then promoted to other countries in Asia, Latin America and Africa, see fig 2 (3-5, 73, 74).

IPM is taught at Farmer Fields Schools (FFS) as an alternative to the 'top-down' extension methods used during the 'Green revolution' where credit for farmers to buy seeds was linked to obligated purchases of other inputs like fertilizers and pesticides (3-5, 14, 73, 74).

To date it is estimated that 10-20 million farmers in 90 countries have been trained on IPM (74, 75). The map below shows countries in which projects with IPM training of farmers in Farmer Field Schools (FFS) have been conducted.

Fig 2 Global reach of FFS trainings in IPM



Waddinton et al. 2014 (75)

IPM lacks a generally accepted definition but is often defined as a coordinated integration of multiple complementary methods to suppress pests in a safe, cost-effective, and environmentally friendly way (3-5, 74, 75).

IPM can have multiple components like seed selection and treatment, soil preparation, seedling nursery and grafting, mulching of soil, host-free periods, cultivation of barrier crops, sticky traps, light traps, pheromone traps, bio-pesticides, biological control with parasitoids and as a last resort pesticides (3-5, 10, 74, 75). Depending on what is included it have various names like IPPM - Integrated Production and Pest Management, emphasizing both the management of natural pests and the production of a healthy crop, ICM - Integrated Crop Management with components including site selection, crop-specific production strategies, nutrient management and cover cropping, ICPM - Integrated Crop and Pest Management combining chemical, biological and cultural pest control methods with crop management strategies (75).

A typical FFS consists of 20–25 farmers, assisted by a facilitator often an agronomist or trained agricultural field assistant. The group meets frequently during the crop season to set up experiments with pest management in one or more crops, often comparing IPM methods with conventional methods. The bottom-up approach with participation and experimentation in the trainings is said to be one of the strength of FFS compared to traditional top-down teaching. Experiences gained by the trained farmers are supposed to be shared with the local community (3-5, 14, 75).

Several reviews and case-studies have evaluated IPM trainings and the general findings are that knowledge on IPM, the use of IPM methods and net revenue increase while pesticide use in terms of spraying intensity and amounts of pesticides used decrease (3-5, 75, 76). The effect of IPM trainings have also shown positive health impacts with increased use of protective measures and a decreasing number of APPs in various surveys (5, 48, 64, 77-79). A follow up survey showed an increase in the use of personal protection from a score of 3.8 to 4.3 of a maximum score of 10 among trained farmers (77). A survey reported fewer signs and symptoms of APP among trained farmers during the season they used IPM methods compared to the season with conventional farming (64). The severity of the poisonings shifted from moderate to mild and the mean number of symptoms and signs decreased from 3.4 to 1.2 over the reporting period (64).

A follow-up survey on performance in neurological tests among trained farmers showed a significant improvement when comparing the cropping season before training with the season after training on IPM (78). In another survey, farmers who had followed IPM training had less cholinesterase inhibition than untrained farmers, probably because the trained farmers used fewer insecticides (48). The quality of the trainings, like the skills of the facilitator, the relevance of the themes, whether or not being open for including local experiences etc. are obviously very important for a successful outcome of IPM trainings as pointed out in various surveys (80-82).

Table 5 shows the results of some surveys evaluating IPM trainings and as can be seen the impacts of the trainings and the methods used vary.

Table 5: Studies on outcome of trainings of farmers on Integrated Pest Management

Ref. no.	Author, publishing year, country, income level	Participants Crops grown Sampling procedures	Intervention	Outcome on IPM knowledge and/or use	Outcome on amount of pesticide use and/or toxicity	Outcome on yields and Gross Margin	Diffusion of knowledge
Follow-up studies							
(77)	Orozco, 2011 Ecuador Middle-income	*359/0/0 Households/crop managers **Non-random sampling	2–3 h every 2 weeks over 3 months Content of pesticide toxicity; pathways of pesticide contamination; symptoms of poisoning and treatment; crop management with an emphasis on IPM	Label reading increases from score 2.6 to 5.3 out of 10 Symptom knowledge increases from score 7.7 to 9.0 out of 10 PPE use increases from score 3.8 to 4.3 out of 10 Awareness of IPM increases from 27% to 56%	Decreased from 0.4 to 0 kg/crop-cycle for WHO class Ib and II		-
(64)	Mancini, 2009 India Middle-income	65/0/0 Cotton farmers, Non-random sampling	Weekly training during the cotton cropping season Content of hazard of pesticide use, pathways of pesticide contamination; handling, application, storage and disposal practices.	Botanical pesticide use increased 15 fold and became the most used pesticide - around 30 % of total use Spraying time reduced from 4.5 to 3 hours per session	15 % reduction in use of organophosphates 31% reduction in use of highly toxic pesticides		-
(83)	Mancini, 2008 India Middle-income	73/0/64 (households) Cotton farmers Non-random sampling	Farmer field schools on IPM during cotton growth season 2002-2003, season long training	Trained farmers doubled different scores on IPM knowledge on pest identification and use of it compared to controls IPM did not require more work to practice than conventional farming	75 % reduction in use of highly and moderately toxic pesticides among trained farmers versus 28 % in controls Total number of applications/ha was reduced from 7.9 to 1.7 among trained farmers compared to 8.2 to 7.2 among controls	No difference in yields as it increased in IPM villages by 19.6% and in control villages by 17.9%	-
(76)	Wu, 2005, In Ooi et al., China Middle-income	51/59/58 Cotton farmers, Random sampling	EU-FAO program with an average length of a season-long training of 75		Pesticide costs decreased in both trained farmers and neighboring farmers compared	Gross margin increased among trained farmers	Maybe

			hours (range: 51-91) Content was organic understanding through cotton ecosystem analysis, field trials and insect zoos.		to controls		
(76)	Khan, 2005, In Ooi et al., Pakistan Middle-income	78/59/53 Cotton farmers, Non-random sampling	EU-FAO program with an average length of a season-long training of 75 hours (range: 51-91) Content was organic understanding through cotton ecosystem analysis, field trials and insect zoos.	IPM skills improved among trained farmers	Number of applications decreased among trained farmers from a mean of 4.33 to 3.76, while doses decreased from 8371 to 4927 ml/ha Costs/ha decreased from 74 to 48 $/ha. No difference in two other groups	Gross margin increased among trained farmers from 140 to 391 $/ha, while no difference in two other groups	no
(76)	Reddy, 2005 In Ooi et al., India, Middle-income	37/30/30 Cotton farmers Non-random sampling	EU-FAO program with an average length of a season-long training of 75 hours (range: 51-91) Content was organic understanding through cotton ecosystem analysis, field trials and insect zoos.	Score for IPM skills improved most pronounced among trained farmers with 33.9 point versus 14.2 and 11.9 in the two other groups. The more knowledgeable on pest management and IPM adopted more IPM practices			no
			Cross-sectional studies				
(84)	Tripp, 2005 Sri Lanka Low-income	70/70/70 Rice farmers Random sampling	IPM training usually 10–15 half-day meetings in a single season	Increased insect control knowledge among trained farmers	Trained farmers sprayed less pesticide than untrained farmers		no
(85)	Mutandwa, 2004 Zimbabwe Low-income	73/73/0 Cotton Non-random sampling	Integrated Production and Pest Management (IPPM) was used among rice farmers incorporating crop management strategies that enhance crop yields apart from pure IPM	Mean score for knowing the actual effect of the pest on the cotton crop for trained farmers and neighboring farmers was 76 and 56% respectively	Average number of spraying per season 8.1 among trained farmers and 14.6 among untrained Pesticide costs was 43% lower among trained farmers	Yield among trained farmers were higher than among untrained (4.9 vs 3.6 cotton bales per acre) Net return was 39% higher among trained farmers	-
(48)	Smit, 2003 Sri Lanka	122/94 Vegetable farmers	Season long training in IPM making use of natural and		Season spraying time with insecticides per ha10.9 hours		-

	Low-income	Random sampling	cultural pest control methods, and of other practices aimed at growing a healthy crop.		for FFS, 58.9 hours for non-FFS Pesticide costs decreased 37.5 $ by FFS, 62.5 $ by non-FFS		
(86)	Rola, 2002 Philippines Middle-income	68/89/146 Rice farmers Non-random sampling	Training with 25-30 farmers who undergo a season long (a half-day meeting each week over a 10-week period). Topics was on plant varieties, seed selection, nutrient, insect and disease management, field sanita-tion, water and weed management.	Trained farmers had a higher knowledge of certified seeds, seed health, nutrient management, and pest management compared to the neighboring farmers and the controls			no
(79)	Hruska, 2002 Nicaragua Middle-income	Varying numbers 31-57/50-70/11-19 Maize farmers Non-random sampling	IPM trained based on monitoring pest populations in the field, correct timing of pesticide applications, minimum dosage of pesticides, correct pesticide choice, and proper maize variety selection.		Increasing trend in average no. of pesticide applications in maize crop from intensively trained farmers to un-trained farmers (no. 0.95-1.45-2.32)	No effect on yields Increasing net return from untrained to intensive trained farmers (-24, 12 to 43 $US/ha)	yes

***trained farmers / neighboring (less trained) farmers / control farmers**
**** If sampling procedure is not indicated or is unclear then the sampling procedure is categorized to be non-random**

In these surveys the trained farmers were almost always selected by their local community to guarantee an impact using criteria's like 'ability to read and write', 'being respected in the village', 'having time to attend the trainings and pass on knowledge to neighboring farmers' and the like.

As seen from the table only some of the surveys used random sampling for the selection of neighboring farmers and controls to be included in the surveys. This is probably due to the nature of the development projects being action-oriented and not research projects complicating setting up too rigorous rules for the surveys used for evaluation of the projects as discussed later.

A restriction or banning of imports of hazardous pesticides could be a very effective method to reduce the number of APPs as one of the risk factors for an APP is the use of hazardous pesticides, see table 3. Such a banning of pesticides has proven very useful to prevent self-inflicted poisonings (87, 88).

In spite of the continuous efforts to promote IPM and the positive results shown in the evaluations, its diffusion from farmer to farmer and mainstreaming into the wider society remain low. Researchers have pointed to various reasons for this such as a too weak control with pesticide imports and sales giving ground for sale of cheap banned or low-quality pesticides, IPM being too complicated to learn, a lack of public policy to invest in national IPM extension services for training farmers, a strong lobbyism by the pesticide companies, pesticides providing an effective and simple answer to the problems farmers are facing, and IPM being too costly to diffuse, among others (74, 75, 80, 82, 89-92).

Chapter 2

The Bolivian Context and the Plagbol Project

2.1 Geography and people

Bolivia is a landlocked country with an area of around 1,000,000 km2 located in western-central South America. Bolivia is a multi-ethnic country with a population of around 10,500,000 people, including Amerindians, Mestizos, Europeans, Asians and Africans, speaking Spanish and many original languages. In Bolivia 45% of the population are living below the national poverty line (2 $US/day). Underemployment reaches 60% and unemployment 15% (93, 94). Bolivia's main income stems from mining, hydrocarbons and agriculture

Fig 3 Bolivia and Latin-America

"Bolivia (orthographic projection)" by Connormah - Own work. Licensed under CC BY-SA 3.0 via Commons.

The present government lead by an ethnic Bolivian, Evo Morales, has increased the growth rate to be around 5% per year and has made Bolivia change from belonging to the group of low-income countries to group of the lower-middle-income countries (93, 94).

The *Altiplano* in the Andean region is in the southwest and spans 28% of the national territory. It is located 3,000 meters above sea level and has a temperate climate. The *Sub-Andean region* is in the center and south of the country between the *Altiplano* and the eastern plains; this region comprises 13% of the territory, it is located between 500 to 3000 meters above sea level and has a temperate to subtropical climate. The *Llanos region* in the northeast comprises 59% of the territory. It is a region of flat land and small plateaus covered by extensive rain forests containing enormous biodiversity. The region is up to 500 meters above sea level and has a tropical climate (94).

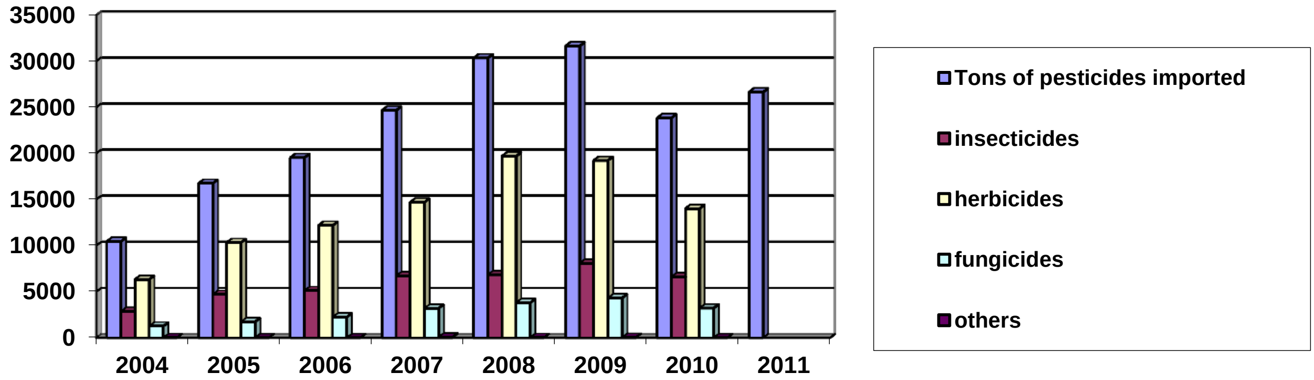
2.2 Agriculture in Bolivia

An estimated 2% of Bolivia's area is cultivated by approximately 700,000 agricultural units. Four hundred thousand units are small-scale farms with a few hectares of cultivated land and livestock, while 300,000 farms are medium- to big-cash crop and livestock farms. The largest areas are owned and run by only a few thousand farmers and investors. The total arable area for agriculture has doubled within the last decades to now 4.5 million hectares in 2012 (12, 13). Industrial crops have increased by 335% from 1980 to 2007 compared to an increase of 20% in traditional crops. As the climate varies from temperate to tropical, a wide variety of crops, such as the traditional potatoes, maize, cereals, vegetables, pepper and fruits are cultivated. Cash crops such as cotton, sugar, soybeans, rice and coffee are cultivated for export (13).

In Bolivia pesticides were introduced in the 1960s among big-holder farmers in the tropical areas and were later taken up by small-holder farmers. During the period 1990-2012 the import of agrochemical products multiplied in value from US$ 6.4 million to US$ 185.1 million (12).

The following figure of pesticide imports during the last decade in Bolivia reflects the boom in pesticide use and classes.

Fig 4 Tons of pesticides imported to Bolivia 2004-10 (95)



Agricultural research and extension services (for guiding and training farmers) have always been weak with little access for small-holder farmers. A state-driven extension service was started in the

19970s and ran until the mid-1990s. With the structural changes and liberalization led by the IMF it changed to become market driven moving further away from the small-holders. From 2005, the extension services again became state-driven offering better opportunities for small-holder farmers. The food security and organic productions became prioritized by legislative initiatives like the “Act of Organic Agricultural Production Regulation and Promotion” (Act 3525) from 2006, the new Constitution from 2009 stating that “The State has the obligation to guarantee the food security through healthy, appropriate and sufficient nutrition for all the population” (article 16) and The Agricultural Productive Community Revolution Act from 2011 “giving priority to organic production in harmony and balance with Mother Earth”(2).

To date Bolivia has adopted a series of international, regional and national regulations and programs aimed at mitigating the risks and/or negative effects of pesticides. In spite of this the results have not been as expected and the regulatory systems, the training and research programs are still weak. Hitherto big donor programs and NGOs have been the most stable and biggest providers of extension services and farmers' education, with sparse coordination with government programs thereby making the efforts less sustainable in the long run (13).

IPM in Bolivian agriculture was introduced in the late 1990s through the International Potato Center (CIP) and its partners focusing on research on potatoes and quinoa, with training and extension services (2, 4, 96, 97). IPM with the development and use of traps to control the Andean potato weevil has been promoted in some areas and schools (98).

A survey from Bolivia compared the effectiveness of diffusing knowledge on potato IPM through FFS, community workshops and radio (96). Community workshops were almost as effective as FFS for teaching most ideas; radio spots were less effective, especially for ideas that require demonstration. They concluded that “the more complicated, tedious, and counter-intuitive a new technology is, the more important it may be to use a more intensive extension method and the less likely that a mass media will be successful”.

In another survey practical lessons were drawn from trainings on potato late blight in Ecuador, Peru and Bolivia where 15 FFS were undertaken (97). The recommendation was to include farmers in planning, to use NGOs if available, facilitators should be properly trained and FFS might play an important role in participatory research among others (97).

Danish Development Aid has been supporting various initiatives on IPM in the Andes region of Bolivia (13, 99).

Agronomists in the Bolivian Ministry of Agriculture and various NGOs tell that these experiences and practices have not been mainstreamed so far but were practiced in restricted areas during the project periods (pers.com. Ing. Jose Lopez, Min. Agriculture).

2.3 The Plagbol project

From 2001 the Bolivian NGO, Fundacion Plagbol, has promoted IPM in a development project implemented in three phases and running until 31 December 2013. The general objective of the project was to 'Contribute to improve the life of farmers by a reduction of the diseases caused by pesticide use, an improvement of the agricultural production and a preservation of the environment.' (2). In a pilot phase from 2001 to 2004 in four Municipalities in La Paz county, sixty farmers were trained in IPM, including good agricultural practices, responsible pesticide use and organic farming.

From 2004 to 2013 the project focus was on advocacy and awareness rising at the national level, spreading the experiences from Phase 1 to relevant public and private institutions (2). The important results have been a change in curriculums trying to mainstream IPM training in Bolivia's Technical Agricultural Schools and at the faculties of Agronomy in the universities. A change in the policy by the Ministry of Agriculture was achieved from relying only on pesticides and having farmers training by the pesticide industry to the actual focus on IPM training of small-holder farmers by the Ministry's own operative branch SENASAG. The National Committee on Pesticides was revitalized from practically being led and financed by the pesticide industry to being led by SENASAG itself and including a variety of other relevant stakeholders. Farmers' Cooperatives on IPM and organic farming were formed together with AOPEB - and during the years thousands of farmers were trained on IPM by the project and partners, see table 6.

Table 6 Timeline for Plagbol Project activities

Plagbol project phases	Agricultural activities in Plagbol	Published surveys from Plagbol
Phase 1 – 2001-2004	2001-02: Start up project activities in 4 Municipalities in La Paz Department 2001-02: Introduction and detailed project planning 2002-04: Teaching of IPM in Farmers Field Schools (FFS) 2002-04: Trained farmers pass on knowledge to neighboring farmers 2002-04: Information on IPM and pesticide toxicity diffused in project area (written material, radio programs)	2002: Baseline survey in 48 project villages with interviews and blood tests on 201 farmers. (60) 2004: First follow up survey to evaluate effects of FFS with interview of 23 trained and 47 neighboring farmers. (Thesis paper 2) 2004: Survey among 48 farmers and 33 controls to evaluate eventual genotoxic damage among pesticide exposed farmers.(31)
Phase 2 – 2005-2010	Project activities expanded to five Departments of Bolivia. Teaching of farmers and technicians from other institutions and municipalities. Advocacy of IPM towards other NGOs, teaching institutions and ministries forms great part of project. Technical agricultural schools in Bolivia elaborate and introduce IPM in curriculum. Ministry of Agriculture elaborates curriculum for training of small-holder farmers on IPM. Technical school of nursery and environmental technicians introduces pesticide toxicity - prevention, diagnose and treatment in curriculum. Teachers Training College and Public schools introduce environmental issues including pesticides in curriculum.	2006: Survey among farmers in La Paz county on genotoxicity in farmers exposed to pesticides.(100) 2008: Survey on pesticide residues in samples of tomatoes.(101) 2008-09: Survey on differences in Gender regarding pesticide knowledge, handling and poisonings including 137 male and 39 female farmers.(102) 2009: Second follow up survey to evaluate long term effects of FFS with interview of 23 trained and 47 neighboring farmers. (Thesis paper 2) 2009: Survey among 191 farmers and 40 pesticide retailers to evaluate pesticide knowledge and storing practices. (Thesis paper 1) 2009: Survey including data from paper 2 and 3 with 23 trained and 47 neighboring farmers compared to 138 farmers to examine a possible diffusion of knowledge from trained to neighboring farmers (Thesis paper 3)
Phase 3 – 2010-2013	The National Institute of Occupational Health opens a department on pesticide poisonings. Project activities consolidated, teaching of farmers goes on. Municipality plan for prevention of negative effects on health and environment due to pesticides elaborated and tried out. Preparation of a new project with focus on pesticide use in vector control programs, solutions for obsolete pesticides and containers and consumer safety takes place, with several studies to document the actual situation.	2007 to 2012: Survey on suicide attempts and suicides in Bolivia.(103) 2012: Survey on diabetes and pyrethroid exposure among 116 vector control program sprayers and 92 controls.(21) 2013: Survey with Focus group discussion among 11 farmers and 5 agronomists. (Thesis paper 4)

2.4 Research activities in the Plagbol project

Few published studies on pesticide and health in Bolivia exists, and the Plagbol project has added considerably to the amount of knowledge on this issue. This research has served for documentation and evaluation purposes and to advocate for actions to mitigate the dangerous effects of the pesticides, apart from the teaching of farmers in the project areas.

The Baseline study

The first survey was the baseline survey from 2002 'Occupational pesticide intoxications among farmers in Bolivia: A cross-sectional study' published in 2006 (60). These data formed basis for the planning of actions on the Plagbol project and the study is an important foundation for this thesis as well.

The survey was conducted among 171 pesticide using male farmers. Interviewer guided questionnaire and blood tests of ChE was realized. Controlled analysis for identification of risk factors for self-reported pesticide poisonings and a lowered ChE was undertaken.

The survey showed a frequent use of highly hazardous pesticides with metamidophos a class 1b pesticide used by 69% of the farmers. Moreover a lack of knowledge on pesticide toxicity, a low use of PPE and appropriate hygiene when handling pesticides were seen.

Symptoms of self-reported APPs were reported by 70% of the farmers past year, with headache, dizziness, tiredness, blurred vision, vomiting and skin irritation being the most common.

When analyzing the individual variables in a controlled analysis the following had increased OR for self-reported APPs: spraying >3 times in the previous months (OR 3.58, 95%, CI 1.44-8.92); the use of OPs (OR 2.96, 95% CI 0.96-9.12); 'no use of gloves' (OR 2.87, 95% CI 0.90-9.11), 'no use of a mask' (OR 2.72, 95% CI 0.96-7.73), 'the habit of blowing/sucking the nozzle of the knapsack sprayer when obstructed' (OR 4.00, 95% CI 1.70-9.45) and 'not reading the instructions on the container before using the pesticide' (OR 3.24, 95% CI 1.19-8.87).

Two aggregated variables, one on frequency of spraying and acute toxicity of the pesticide used and another on the number of PPEs and hygienic measures realized when spraying, was show to be risk factors for self-reported APPs after spraying past month, see table 7.

A lowered ChE was depending on spraying frequency and the toxicity of the pesticide in an aggregated variable whereas no connection was found regarding the number of PPEs and hygienic measures realized when spraying. The only significant individual variables of importance for a lowered ChE was spraying with OPs or not (mean ChE activity 7.11 kU/L vs. 8.03 kU/L, p<0.01), and reading instructions on the pesticide container before use or not, (mean ChE activity 7.46 kU/L versus 6.84 kU/L,p=0.02).

The survey is attached as annex 1.

Table 7 - Odds Ratio (OR) for having experienced symptoms of acute pesticide poisoning after spraying past month according to exposure status among male farmers (n=114)

	%	Unadjusted		Adjusted*	
		OR	95% CI	OR	95% CI
Sprayed only pesticides other than organophosphates (OPs) past month	22	1(ref)	-	1(ref)	-
Sprayed from 1-3 times with OPs past month	45	2.04	0.70 - 5.99	1.91	0.58 - 6.30
Sprayed more than 3 times with OPs past month	33	6.09	1.96 - 18.97	5.97	1.63 - 21.96
>7 precautions taken when handling pesticides	17	1(ref)	-	1(ref)	-
6-7 precautions taken when handling pesticides	33	5.63	1.37 - 23.06	5.15	1.17 - 22.67
4-5 precautions taken when handling pesticides	32	4.17	1.01 - 17.18	5.19	1.15 - 23.42
0-3 precautions taken when handling pesticides	18	10.83	2.25 - 52.20	13.88	2.60 - 74.11

Logistic regression analysis, * the OR were mutually adjusted.

Other surveys from Plagbol

Other causes of acute pesticide poisonings have been studied as seen from table 6. A paper on suicides ‘Suicide attempts and suicides in Bolivia from 2007 to 2012: pesticides are the preferred method - females try but males commit suicide!’ was published in 2014. This paper shows pesticides to be the most frequent method for suicidal attempts and underlines the need for restricted imports and sale as well as safe pesticide storage out of reach of children and non-users.

A paper on risks of acute and chronic food poisonings by pesticide residues on tomatoes ’The influence of tomato processing on residues of organochlorine and organophosphate insecticides and their associated dietary risk.’ was published in 2015 (101). This paper shows both an acute and a cumulative dietary risk for poisoning with organophosphates when consuming untreated tomatoes three days after harvest. The risk for adults disappeared by washing or peeling tomatoes, where a risk was still seeing for washed tomatoes among children. Traces of obsolete and banned pesticides were found in the analysis.

A paper on gender, ‘Is Gender a Risk Factor for Pesticide Intoxications among Farmers in Bolivia? - A cross sectional study.’ was published in 2013 (102). This paper showed females being less educated, using less personal protection when handling pesticides and more often complaining of APP.

Possible chronic effects of pesticide poisoning have been studied in two published papers, one in 2007 named ’Genetic Alterations in Pesticide Exposed Bolivian Farmers: An evaluation by analysis of chromosomal aberrations and the comet assay.’, and one in 2014 named ’Is cumulated pyrethroid exposure associated with prediabetes? A cross-sectional study.’ (21, 31). The first survey showed increased genetic damage among farmers spraying pesticides, which in the long run might increase their risk for contracting cancer (31). The other survey suggested an increased prevalence of pre-diabetes among spray-men spraying pyrethorides, which has been found in a few other studies on pyrethroid exposed workers (21).

In summary, the studies have helped justifying the Plagbol efforts in Bolivia by shedding light on acute and chronic health problems due to pesticides and have increased the information on pesticide dangers in Bolivia.

Chapter 3

Objectives of the thesis

The **overall objective** of this thesis is to estimate the prevalence of known risk factors for occupational related acute pesticide poisonings, discuss the extent of the poisonings and the role of Integrated Pest Management as a strategy in preventing such episodes among small-holder farmers in Bolivia.

Specific objectives:

- To discuss the extent of acute occupational pesticide poisonings among small-holder farmers.
- To assess the prevalence of risk factors for occupational pesticide poisoning among Bolivian small-holder farmers.
- To evaluate the ability of an IPM training program to reduce pesticide exposure and self-reported acute pesticide poisonings among Bolivian small-holder farmers.
- To evaluate the diffusion of knowledge and practices from IPM trained farmers to their neighboring farmers.
- To discuss the barriers and possibilities for a wider mainstreaming of IPM among small-holder farmers.

The thesis will help adding to the scarce knowledge on small-holder farmers' use of pesticides and explore possibilities for prevention of the negative health impact and pollution from pesticides in Bolivia.

Chapter 4

Methods

In this chapter, an overview of the Methods used in each of the four surveys is presented, while in each of the papers included in chapter 5-7 a more complete description of Methods is given.

The first three surveys were quantitative epidemiological surveys while the fourth was a qualitative survey, see table 8.

Table 8: Overview of the surveys presented in the thesis

Survey no.	Aim of the survey	Survey questions	Methods	Participants	Survey periods
1	To describe the amount, types and storing of pesticides on farms and in retail stores and evaluate farmers and retailers knowledge on pesticides	How frequent are acute pesticide poisonings among Bolivian small-holder farmers and which are the risk factors?	Cross-sectional survey interviews and observations	191 farmers 40 pesticide retailers	2009 August to September
2	To evaluate if education of farmers on IPM can lower pesticide use, improve personal protection and decrease number of farmers with self-reported APPs	What is the effect of training Bolivian small-holder farmers on IPM in terms of pesticide use, personal protection and self-reported acute pesticide poisonings?	Follow-up survey interviews	23 trained IPM farmers 47 neighboring farmers	2002, March to April 2004, October to November 2009 , September to November
3	To evaluate if IPM Methods can be disseminated from trained farmers to their neighboring farmers	Can knowledge and practice of IPM be disseminated from trained Bolivian small-holder farmers to neighboring farmers?	Cross-sectional survey interviews	23 trained IPM farmers 47 neighboring farmers 138 control farmers	2009, August to November
4	To describe possibilities and obstacles to a diffusion of IPM from trained farmers to their neighboring farmers	Can knowledge and practice of IPM be disseminated from trained Bolivian small-holder to neighboring farmers?	Qualitative survey focus group discussions	11 farmers 5 agronomists	2013 September to November

4.1 Survey areas

The survey included 70 villages or hamlets from nine Municipalities in La Paz Department and one in Santa Cruz Department, see fig 5.

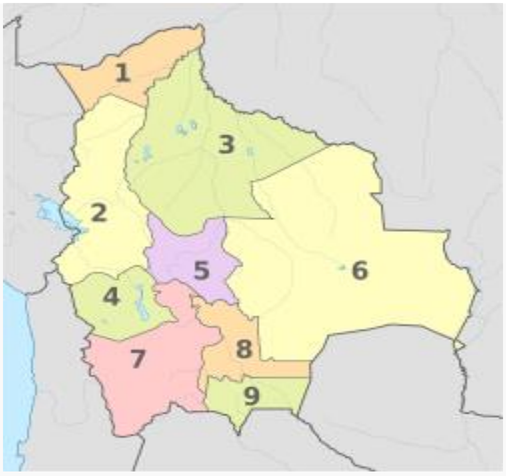
The population in the Municipalities consists mostly of small-holder farmers and the number of citizens in each Municipality varies from 6,000 to 27,000 persons, and in the villages from below a hundred and up to 500 persons (97, pers. com. Plagbol personnel).

A wide variety of crops is grown depending on the climate varying from subtropical to temperate within short distances due to different altitudes in the Andes Mountains. The most frequent crops are cereals, vegetables and fruits. The growth season is from late September to June for most crops, and intensive spraying with pesticides takes place in the months of November to April.

The surveyed Municipalities were part of the project intervention areas, or control areas with farming circumstances resembling those of the project areas. The villages for the intervention were chosen after consultations with local Farm Union leaders as being accessible by car or boat almost the whole year round.

Photos of pesticide handling in project areas - see Annex 2

Fig 5 Departments of Bolivia



Administrative territorial division of Bolivia

No.	**Department**
1	Pando
2	<u>**La Paz, Survey 1-4**</u>
3	Beni
4	Oruro
5	Cochabamba
6	<u>**Santa Cruz, Survey 4**</u>
7	Potosi
8	Chuquisaca
9	Tarija

"Bolivia, administrative divisions - Nmbrs - colored" by TUBS - Own work. Licensed under CC BY-SA 3.0 via Commons.

4.2 Survey participants

The participants were small-holder farmers, pesticide retailers and agronomists.

<u>Survey no. 1</u>: In 2009, a cross-sectional survey was conducted to describe the stores of pesticides on small-holder farms and in retail stores and evaluate farmers' and retailers' knowledge on pesticides.

This survey included one hundred and ninety farmers and forty pesticide retailers. The farmers were interviewed when they happened to be at home when visited by the interviewers and the retailers when participating in a course or when visited in their shops or on the market.

Survey no. 2: In 2002, 2004 and 2009, a baseline and two follow-up surveys including seventy male farmers were conducted to evaluate if training of farmers on IPM could lower pesticide use, improve personal protection and decrease the number of self-reported APPs.

Of the seventy farmers twenty-three participated in the IPM trainings and the rest were neighboring farmers from the same villages. Initially in 2002, 40 farmers were selected by their neighbors in the villages to go for the trainings, but because many of them changed to organic farming, migrated, changed profession etc., we ended up with 23 farmers for the follow-up surveys. A control group of neighboring farmers was invited to participate when they happened to be at home when the interview in their village with the trained farmer was conducted.

Survey no. 3: In 2009, a cross-sectional survey was conducted to see if IPM methods were likely to have been disseminated from trained farmers to their neighboring farmers. The trained and the neighboring farmers from the follow-up survey were compared to a control group of one hundred and thirty-eight pesticide using male farmers. This control group came from villages in neighboring Municipalities without IPM trained farmers. They were interviewed on their farms when the interviewers visited their villages.

Survey no. 4: In 2013, Focus Group discussions were conducted to describe possibilities and obstacles to a diffusion of IPM with the participation of 11 farmers and 5 agronomists from La Paz and Santa Cruz Departments. The participants were selected by the Plagbol personnel known to have been involved in the IPM trainings and diffusion during the project period.

In all the surveys we excluded female farmers as there was a skewed gender distribution in the groups being surveyed. A later survey from the project showed significant gender differences on spraying frequency, knowledge on pesticides and protective measures undertaken when handling pesticides justifying the exclusion of female farmers (102).

4.3 The Intervention - IPM training of farmers to prevent pesticide poisonings

To prevent occupational poisonings among farmers, an intervention was planned consisting in IPM trainings with organic pest management methods, proper seed selection, crop rotation, irrigation and use of natural fertilizers. Important parts of the training were ‘knowledge of negative health effects of pesticides', 'proper use of PPE and personal hygiene when handling pesticides' and 'how to pass on IPM knowledge to neighboring farmers'.

The intervention took place from 2002 to 2004 and consisted in FFS training of farmers on IPM. The FFS farmers were trained during 14 courses of two days' duration each, being both theoretical and practical. Booklets for the seven theoretical modules were developed on the following themes: 1. Pedagogic, 2. The World of Pesticides, 3. The Use of Pesticides, 4. Agricultural Pests, 5. Health Effects of Pesticides, 6. IPM Methods and 7. IPM in Tomato farming. A draft version of the booklets was used in each training course and then modified according to the input from the farmers before a final version was distributed among farmers.

During the trainings, the transfer of knowledge from trained farmer to neighboring farmer was facilitated through training on pedagogical methods, rehearsal of hands-on training situations and elaboration of personal teaching materials such as flipcharts, herbarium and insect collections.

A minimum of two informative trainings in each village on IPM and adequate use of pesticides were held by the trained farmers in their own villages. The first village training was supervised by a Plagbol employee to give feedback to the trained farmer on his performance. All trained farmers have confirmed to have implemented two or more training session in their villages. According to the trained farmers and the Plagbol supervisors, the neighboring farmers have to a large extent taken part in these informative village meetings and trainings (pers. com., Plagbol staff). Attendance was facilitated by a strict control where farmers are fined if they do not attend village meetings arranged by the Farmers' Union.

Informal knowledge sharing from FFS farmer to neighboring farmer also took place on a day to day basis in the villages according to information from both the FFS and the neighboring farmers, but the extent of this is not known as no record was kept.

In the project phase two from 2004 to 2009 after the trainings stopped in the first phase villages, IPM information was spread through radio and television programs, newspaper articles and informative materials about pesticides throughout Bolivia. This has been done in a scale of approximately 30 radio, 15 television programs and 100 newspaper articles. Similar information has to some extent been relayed by other NGOs, pesticide companies or the Ministry of Agriculture. Training and information materials can be downloaded from www.plagbol.org.bo and seen at https://www.youtube.com/channel/UC13WXDnAuqp1zaquxJyiE6Q.

Photos of IPM trainings in project areas - see Annex 3

4.4 Data collection tools

Data were collected through interviewer guided questionnaires (see annex 4), focus-group discussions and observations on spot.

The Plagbol project staff collected the data supported by Bolivian and Danish professionals, students and farmers.

The questionnaire consisted of closed and open-ended questions, including 1) age, sex, education, family status, diseases and smoking habits, 2) size of cultivated land, crops grown, pests affecting the different crops and pest control used by the farmers; 3) knowledge, attitudes and practice when buying, handling and storing pesticides; and 4) perceived health impact, knowledge of pesticide dangers, experiences with APPs and symptoms of pesticide poisoning in connection with spraying.

When poisonings were assessed, the interviewed person was asked if he had felt ill in connection with spraying during the past year or month, and if the answer was yes, he was asked to specify which symptoms he had experienced. The interviewer could mark symptoms on a pre-elaborated list or add symptoms if they were not on this list.

Before conducting the interviews, training sessions for the interviewers were applied.

The questionnaire was piloted among 15 farmers and corrected if found necessary before being used at a larger scale. A mean Kappa-value of 0.73 and an inter-observer agreement of 86% were calculated.

Survey 1-3 used the questions elaborated at baseline in 2002.

In **survey 1** data was collected by questionnaire, on-site observations and measurements. The observational data included information about the amount and type of pesticides in stocks, and the safety of pesticide stores. Data was collected using a stockpile and workplace checklist. Amounts of pesticides in farmers stocks were measured by the Plagbol staff by weighing the obsolete pesticides when found in the stores on the farms.

In **survey 4** a guide for the Focus Group Discussions on possibilities and obstacles for a diffusion of IPM was used. The guide was inspired from Roger's theory on 'Diffusion of Innovations' (104). This theory offers tools to describe how, why, and at what rate new ideas and technologies spread, including four elements of importance for diffusion: the innovation itself, the communication channels, a time factor, and the social system. For this survey, these issues were adapted to focus on the innovation and the possibilities to make alliances for spreading the innovation. The FGDs included but were not restricted to the following themes: 1. Comparative advantage - evaluated by comparing IPM and traditional agriculture on the need of investments, labor demand, size and value of the yield. 2. Compatibility - evaluated by how easy IPM fits into ‘preservation of Mother Earth’ (local synonym for the environment), agricultural practices in use, and norms and regulations given by the state. 3. Complexity - evaluated by the ease of understanding the innovation, and the complexity of the new method. 4. Triability - evaluated by the cost of trying out IPM, the ease of using the practices, and the ease of detecting short-term results. 5. Observability – evaluated by the perceived size of the yields and the quality of the products, 6. Re-invention – evaluated by the ease to improve IPM methods by adapting new ideas and experiments and trials and 7. The creation of alliances – evaluated based on the ease to build relations and sharing the IPM experiences with others.

Each Focus Group (FG) was told to come up with one joint score on each of the themes discussed and support their categorization of this scoring with a couple of arguments on why they scored as they did (for more details see paper 4).

4.5 Literature search

The literature search was systematized by using search strings with relevant key-words and took place in connection with the planning of the surveys when writing the articles and writing up the PhD. The literature was gathered from 2001 to November 2015. The databases PubMed and Web of Sciences as well as Google were used for the search. The strategy was broad with the search strings depending on the subject of each survey. For the baseline paper the search string ‘pesticide’ and ‘poisoning’ and/or ’intoxication’, and/or low-income countries, and/or developing countries was used. For paper 1 the search string ‘pesticide’ and ‘storage’, and/or ‘pesticide retailers’, and/or ‘sale’, and/or low-income countries, and/or developing countries was used together with the search string for paper 1. For the papers 2 to 4 the search string ‘pesticide’ and ‘prevention’ and/or ‘IPM’, and/or ‘Farmer field schools’, and/or ‘low-income countries’ was used.

Some of the articles were found in the references to the extracted articles from the databases and some articles were forwarded by colleagues. The articles were evaluated by headlines, abstracts and content with emphasis on methods, size of the study and geography to get a broad representation of studies from mainly middle- and low-income countries. The literature search was done in English, although some of the papers are in Spanish being identified and forwarded by the Plagbol project staff.

4.6 Data handling and analysis

The data was entered into Epidata and Excel, revised, cleaned and transferred to SPSS version 21 by a Bolivian data-manager. The PhD student recoded the data when necessary and performed the analysis. The Focus group discussions were transcribed from taped records, by a Bolivian consultant, and systematized and analyzed by the PhD student.

Apart from the variables given in the questionnaire, new variables were created such as the mentioned commercial names of pesticides recoded into their WHO toxicity classes, and different aggregated variables on exposure created based on the toxicity of the pesticides used, the personal protective equipment used and the hygiene measures. Aggregated variables were either dichotomized or kept as numerical variables depending on the analysis. The soundness of aggregating variables can be discussed but it is our opinion that an aggregated variable might express a better picture of the real exposure level as the exposure depends on a variety of circumstances when handling pesticides and not only one.

The data was analyzed using sound statistical methods including simple frequency analysis, $\chi 2$-test, linear by linear association, t-test, paired t-test, ANOVA and non-parametric tests. In study no 3 confounding by age education and living altitude were analyzed and controlled for by stratification, (for more details see papers 1-3). The other Plagbol studies, although not being among the PhD papers included linear, logistic and Poisson regression analysis with control for relevant confounders.

4.7 Ethical considerations

The Medical Ethical Committee of Bolivia gave its approval of the surveys and The Plagbol Foundation holds the rights to collect information for evaluation of its activities. There were no objections for taking the data out of Bolivia for analysis. All participants were informed about the surveys before participating and had the right to withdraw at any point in time during the survey. They signed an informed consent before being enrolled in each survey and had the right to withdraw at any point in time during the surveys. All the surveys were found to be in compliance with the Helsinki Declaration.

Chapter 5

How frequent are acute pesticide poisonings and risk factors of poisoning among Bolivian small-holder farmers and pesticide retailers?

In this chapter a summary of the results from the survey no. 1 and the paper in its full length is presented.

5.1 Summary of results

The use of highly toxic pesticides was observed on the farms where most of the pesticides stored belonged to the WHO toxicity class I and II (285/312, 91%). According to the pesticide retailers these pesticide classes were also the most sold.

In the farm storages the majority of the pesticides (187/312, 60%) were obsolete defined by lacking an intact label, lacking the Ministry of Agriculture stamp, being outdated, without expiry date on the container, prohibited for use in Bolivia or not stored in the original container. Pesticides were most often stored unlocked (108/191, 57%) and/or within the reach of children (94/181, 55%).

The extremely hazardous and/or banned pesticides like aldrin, dimethoate and parathion was also found in farm storages although they are not allowed for import to Bolivia or banned through international treaties ratified by Bolivia.

In the retailers shops pesticides where often stored close to other farm products, the shops were overcrowded and lacked good ventilation. Some had minors working in the shop and sold pesticides to minors.

The general knowledge on proper pesticide handling and practice was poor. The knowledge of the color on the pesticide containers signalizing the toxicity of the pesticide was unknown to a majority of the farmers (101/191, 53%). Fewer retailers did not know the meaning of the toxicity labeling on the pesticide containers (16/40, 40%).

A minority of the farmers used appropriate personal protection like gloves or apron (74/191, 38.7%, and 14/191, 7.3%). Retailers were a bit better than farmers in using protective devices, but did not perform as many hygienic measures as farmers.

This lack of knowledge and use of personal protection has been shown to be risk factors for pesticide poisonings as seen from table 3 and in our baseline study and 33% (62/169) of the farmers in the actual survey reported having experienced episodes of pesticide poisoning after spraying the past year compared to 17.5% (7/40) of the retailers.

The same results including a more detailed picture of pesticide knowledge, attitude and practice among small-holder farmers is seen in the surveys no. 2-3 presented in the following chapters, and in the baseline survey in annex 1 (60).

The findings in paper 2 and 3 and in the baseline survey confirm the frequent self-reported pesticide poisonings, a poor knowledge on pesticide toxicity and poor personal protection when handling pesticides. The baseline paper moreover showed that poor knowledge and handling practices was risk factors for the experience of poisoning symptoms and a lowered ChE (60).

5.2 Paper 1: "Sale, storage and use of legal, illegal and obsolete pesticides in Bolivia."

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SOIL & CROP SCIENCES | RESEARCH ARTICLE

Sale, storage and use of legal, illegal and obsolete pesticides in Bolivia

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Abstract: Unregulated selling practices, bad storage habits and the use of illegal pesticides in Bolivia are widespread, with increasing negative consequences on public health and the environment. The present study describes the selling, storage and use of legal, illegal and obsolete pesticides among pesticide retailers and farmers in Bolivia. A cross-sectional study was conducted on 191 pesticide-using farmers and 40 pesticide retailers. Data were gathered in 2009 in La Paz County, Bolivia. A questionnaire was used to evaluate pesticide handling practices and observational data on pesticide stocks and storage was assessed through direct visits on site. Banned, outdated and highly toxic pesticides were found stored on most smallholder farms. A mean of 299 g of pesticides was found on each farm, of which 60% were obsolete. Knowledge on pesticide toxicity and safe handling practices were lacking among both retailers and farmers, and poisonings were frequently reported. Significant figures of obsolete pesticides were found outside of the officially recognized dumping sites. This underlines the necessity of including the small but numerous amounts of pesticides stored at farms, when calculating a country's total amount of obsolete pesticides. Better regulations of imports, sale and storage and an improved use of safety measures when handling pesticides needs to be urgently addressed.

Subjects: Environment & Agriculture; Environmental Studies & Management; Environmental Change & Pollution; Environment & Health; Occupational & Environmental Medicine; Occupational Health & Safety

Keywords: pesticides; agriculture; obsolete pesticides; pesticide retailer; low-income countries

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PUBLIC INTEREST STATEMENT

Unregulated pesticide use in low-income countries are a widespread problem, with increasing negative consequences on public health and the environment. In many low-income countries, pesticides no longer in use are being accumulated in larger dumping sites and in farmers' own properties, when in reality they ought to be disposed of to prevent environmental pollution and harm to the surrounding wildlife and populaces. The present study describes the selling, storage and use of legal, illegal and obsolete pesticides among pesticide retailers and farmers in Bolivia.

In this paper, an obsolete pesticide is defined as a pesticide with at least one of the following characteristics; (a) lacking an intact label, (b) lacking a Ministry of Agriculture stamp, (c) being outdated, (d) not showing expiry date, (e) being prohibited for use in Bolivia or (f) not stored in its original container.

1. Introduction

Widespread pesticide use in low-income countries has entailed a number of challenges to human health and the environment over the past few decades. Agrochemicals have been imported to low-income countries and economies in transition since the late 40s, mainly in an attempt to control vector-borne diseases or to be used in the agricultural sector as crop protection. Today, however, selling practices of agrochemicals have become highly problematic. In many low-income countries, pesticide imports are sold to licensed retailers via wholesalers, who then supply the end users, predominantly farmers and livestock keepers. Each of the distributional steps is characterized by bad pesticide handling, poor regulatory control, illegal trade and poor knowledge of their inherent danger (Pereira, Boysielal, & Siung-Chang, 2007; United Nations Environment Programme Chemicals [UNEP], 2003). Access to pesticides is often uncontrolled and challenges, such as unauthorized dealing and selling to minors, have previously been documented (Pereira et al., 2007; Yang et al., 2014). Highly toxic pesticides can be found on the streets, in markets and are available almost anywhere to anyone. Also, great informational deficiencies in every chain of transaction between buyer and seller exists, where pesticide retailers commonly act as the main source of information on pesticide toxicity and handling to the users (Stadlinger, Mmochi, & Kumblad, 2013; Yang et al., 2014). Despite the key role retailers seem to play as information source to the pesticide users, they remain a poorly studied group in scientific literature.

Another problematic aspect of widespread pesticide use is the ongoing stockpiling of toxic chemical waste in low-income countries. Pesticides that are outdated, banned or simply unwanted are accumulating in inadequate storage sites and are posing a serious threat to the safety and health of the local populaces (Aqiel Dalvie, Africa, & London, 2006; Dvorská et al., 2012). In places where public resources are limited and clean-up is pricey, pesticide-using farmers might end up with large quantities of chemicals on either their properties or other unofficial dumping sites, since they lack the knowledge and the means to safely remove them (Aqiel Dalvie et al., 2006; Dasgupta, Meisner, & Wheeler, 2010; Haylamicheal & Dalvie, 2009). Stockpiles are found badly sheltered or even outdoors, which leaves them exposed to a diverse climate including heavy precipitation, thus risking leakage and corrosion. This may cause the chemicals to disperse and contaminate the surrounding soil and groundwater (Alamdar et al., 2014; Dvorská et al., 2012; Querejeta et al., 2012). Contamination of food products, such as eggs and milk, after pesticide dumping or drift from near-by spraying has also been described (Asmus et al., 2008; Essumang, Asare, & Dodoo, 2013; Gałuszka, Migaszewski, & Manecki, 2011; Hernández, Vidal, & Marrugo, 2010; Veiga, Silva, Veiga, & Faria, 2006).

In Bolivia, where nearly half of the population earns their living through the agricultural sector, import of pesticides has increased with a factor 2.5 over the last decade (Food and Agriculture Organization of the United Nations, 2013). The country's obsolete pesticides, including contaminated earth, building materials and containers, in known stocks were calculated to be approximately 614,619 kg in 2011, which is an increase of 62.4% since 2003 (Food and Agriculture Organization of the United Nations, 2003, 2013). The number of pesticides alone in 2011 was 377 tons (Food and Agriculture Organization of the United Nations, 2013). This increase has naturally been a challenge for the Bolivian Ministry of Agriculture in efficaciously managing pesticide handling and usage. Calculations of what farmers have at home of obsolete and other pesticides have to our knowledge never been described, but there is a possibility, due to practical reasons, that large amounts of pesticides are being stored at home. Previous research show that the regulation of pesticide imports and sales is poor, that little knowledge of safe pesticide use is common, and that there is inadequate use of personal protective equipment (PPE) among farmers in Bolivia (Jørs et al., 2006, 2013). In addition, evidence of the negative health effects of pesticides is increasing globally, including in Bolivia (Arrebola et al., 2012; Jørs et al., 2006, 2007, 2013, 2014; Mercado et al., 2013), which has led to many international restrictions and bans on pesticide import and sales, where also Bolivia has signed treaties (UNEP, 2001; United Nations Treaty Collection, 1998).

The aim of the present study is to describe selling practices of agrochemicals among pesticide retailers as well as the management and storage of obsolete pesticides by Bolivian farmers. The results of this study will add to our understanding of the hazards of sale and use of unregulated and obsolete pesticides, and will bring us closer to addressing the problems of widespread pesticide use in small-scale farming.

2. Materials and methods

The data in this article was collected as part of the PLAGBOL project. The study sample included a total of 231 cases, divided into 191 farming households and 40 pesticide retailers, surveyed in 2009. The study area (see Figure 1) consisted of small villages in La Paz County. Of the 2.7 million people in the county, a calculated 170,000 families live in farming households (pers.comm. PLAGBOL, 2009). The area has 52 officially registered pesticide retailers (Ministerio de Desarollo Rural y Tierras, 2009), but the number might be more than tripled, considering the numerous street and market vendors mostly selling illegal or non-certified pesticides. The villages included were situated in the Altiplano and in the surrounding valleys, with their climate varying from temperate to subtropical, making it possible to grow a variety of crops, such as maize, potatoes, fruits, coffee, tea, groundnuts and cereals.

Figure 1. Map of study area with La Paz County marked in dark grey.

2.1. Participants and information gathering

Thirty pesticide retailers from La Paz were volunteers recruited at a pesticide safety workshop conducted by PLAGBOL. The remaining 10 pesticide retailers were recruited at their stores in La Paz. Inclusion criteria for the pesticide retailers were that they (1) were at least 18 years of age, (2) had been employed selling pesticides in the same conditions for at least one month and (3) were employed in La Paz, Bolivia. Interviews were performed by Spanish speaking personnel from the non-governmental organization (NGO) PLAGBOL, and all of the recruited pesticide retailers were able to complete the study.

Farmers were recruited through visits to their village by interviewers going from house to house and inviting them to participate on a voluntary basis when found at home or in the field. The villages included were the villages of Aymara (indigenous nation) female farmers having attended a course on integrated pest management and later volunteering to participate in the study as interviewers in collaboration with the PLAGBOL team. This approach was chosen, as it secures trust between the study team and the farmers, enables a high response rate and prevents cultural misunderstandings, since the interviewers were farmers from the same villages themselves. Before data collection, all interviewers were trained in using the questionnaires, instructed in which observations to make and how to assess the quantities of pesticides found on the farms by weighing of the pesticides or measuring the cc's with a syringe if the pesticides were liquids. The goal was to get approximately 200 smallholder farms surveyed, of which 198 were executed and 191 could be included in the study. Inclusion criteria for the farmers were that they had personal experience with pesticide-spraying operations and that they were over the age of 18. Interviews with farmers were performed in either Aymara or Spanish.

For both groups, descriptive data was gathered through a questionnaire and observational data through direct visits on site. The survey data included information about pesticide stocks, the handling, storing and reuse of pesticide containers, the participants' knowledge and experience with pesticide use, the hygienic measures taken by farmers and retailers, and the safety and hygiene of pesticide stores.

The questionnaire was formed as a semi-structured face-to-face interview, lasting about 1 h and was based on pilot-tested questions used in previous studies (Jørs et al., 2006, 2013). Observational data on pesticide storage practices and employee workplace habits was collected using a stockpile and workplace checklist (Appendix A).

2.2. Data analysis and ethics

Results from the interviews and observational audits were entered into Excel and SPSS, and descriptive statistics were applied, as well as χ^2 test for comparing pesticide retailers with farmers where possible. To get an estimate on the average amounts of obsolete pesticides on each farm, variables were formed by aggregating the amounts of pesticides in the containers with the following characteristics putting them into the category as obsolete: date of expiry can not be seen on container label, date of expiry has passed, pesticides are not in their original container, container has not got a label with product information on it, pesticide are not allowed for use in Bolivia, the container has not got the Ministry of Agriculture stamp on it. The quantities of pesticides found in farmers stockpiles were measured in grams and cc's. To get an overall estimate of the amounts on each farm, the cc's and grams were summed assuming that one cc weighs one gram.

Confidentiality was assured and no incentives were offered for participation. The study was in compliance with the Helsinki Declaration and a written informed consent was obtained by each participant prior to study start.

3. Results

3.1. Demographics, knowledge and experience with pesticides

The farmers were slightly older than the pesticide retailers. There were more females among the retailers and the retailers were also better educated (Table 1). Significantly more pesticide retailers reported that they had received training in safety and handling of pesticides. This was, however, not reflected in their knowledge or practice when handling pesticides, since no significant difference

Table 1. Descriptive data on Bolivian pesticide retailers (*N* = 40) and farmers (*N* = 191)

Variable		Student's *t*-test, *p* value
Mean age in years (SD)		
Farmer	44.3 (11.28)	<0.001
Retailer	35.3 (11.33)	
		χ^2-test, *p* value
Sex (Females)		
Farmer	152/191 (27.2%)	<0.001
Retailer	23/40 (57.5%)	
Education (Primary school or less)		
Farmer	95/191 (49.7%)	<0.001
Retailer	10/40 (25%)	
Can read Spanish		
Farmer	182/191(95.3%)	0.53
Retailer	39/40 (97.5%)	
Have received courses in pesticide handling		
Farmer	81/191 (42.4%)	<0.001
Retailer	30/40 (75%)	
Knows colour of most toxic pesticide		
Farmer	90/191 (47.1%)	0.14
Retailer	24/40 (60%)	
Use gloves when handling pesticides		
Farmer	74/191 (38.7%)	<0.001
Retailer	35/40 (87.5%)	
Use apron when handling pesticides		
Farmer	14/191 (7.3%)	<0.001
Retailer	18/40 (45%)	
Wash hands after pesticide handling		
Farmer	182/191 (95.3%)	<0.001
Retailer	27/40 (67.5%)	
Change clothes after pesticide handling		
Farmer	123/191 (64.4%)	<0.001
Retailer	13/40 (32.5%)	
Eats at work/while handling pesticides		
Farmer	60/191 (31.3%)	0.26
Retailer	9/40 (22.5%)	
Has felt ill after handling pesticides within the last year		
Farmer	62/189 (32.8%)	0.06
Retailer	7/40 (17.5%)	

Table 2. Farmers' buying of pesticides and their relationship with pesticide retailers

Variable	Number (*N*)
Knows what to buy and what the pesticide is used for	121/190 (63.7%)
Use advice from pesticide retailers for choosing the right pesticide	133/188 (70.8%)
Buy their pesticides from a pesticide retailer	132/191 (69.1%)
Receives advice from retailer when buying pesticides	153/190 (80.5%)
Buy pesticides in original container	181/191 (94.8%)

was seen among the two groups on knowledge of pesticide toxicity as expressed by the colour code on the containers (see Table 1). Likewise regarding safety measures, such as personal hygiene when handling pesticides, farmers tend to be more careful than pesticide retailers. This might reflect the more direct contact farmers have with pesticides when mixing and spraying, in comparison with the retailers who only sell the products (see Table 1). The majority, but not all of the farmers, buy their pesticides from pesticide retailers, often being the farmers' only source of information when choosing a pesticide and getting knowledge on how to use it (see Table 2).

3.2. Observation of pesticide retail stores and farmers stockpiles

As seen from Table 3, many of the pesticide retail stores lack basic conditions for safe sale and storage of pesticides. Seven of the stores were crowded and were estimated to be over 60% capacity. Food was being sold within 25 m distance of eight stores, often outside the front door by street vendors, even though none of the pesticide retailers reported selling food themselves. Most worrying is that only half of the stores sell PPE for handling pesticides, less than half use relevant PPE themselves, some have children as sellers in the shop and one subject even reported selling pesticides to children (Table 3). The pesticides most frequently sold by the retailers were reported as WHO class II (57.1%), WHO class I (23.2%), WHO class U (14.3%) and WHO class III (5.4%).

Almost 90% of all the pesticides stored on farms belonged to either WHO class I or II (Table 4) in accordance with what the pesticide retailers sell. Pesticides most often belonged to the chemical class of organophosphates and pyrethyroids. By commercial names, Tamaron (32.5%) was the most commonly found pesticide, followed by Karate (26.2), Folidol (6.3%) and Mapex (5.2%). All four are insecticides and belong to WHO toxic class I and II. 59.9% of the stored pesticides were found to be obsolete characterized by either lacking an intact label, lacking a Ministry of Agriculture stamp on the container, being outdated or not showing expiry date, being prohibited for use in Bolivia or not stored in their original container, as seen from Table 4. A minority of the farmers stored their pesticides locked up and a majority were reachable by children. The mean number of grams of pesticides stored per farm was 299 g (0–2500 g), corresponding to a mean of approximately 180 g of obsolete pesticides per farm.

3.3. Pesticide intoxications

Farmers reported more symptoms of intoxication after handling pesticides than retailers did (Table 1). Farmers' knowledge and experience with pesticide intoxications was investigated and 95.5% of the farmers knew of a serious pesticide intoxication in their village within the last year. Twenty-four per cent of these were due to accidents, 20% due to occupational accidents and 60% were due to suicide attempts. 6.1% farmers knew of a deadly pesticide intoxication in their village within the last year, of which 7.1% were due to occupational accidents and 92.9% were due to suicides.

4. Discussion

The present study identifies a number of negative trends seen in the study population of pesticide retailers and pesticide-using farming households in La Paz district. Illegal and obsolete pesticides were found in the farmers' personal inventories, including banned and highly toxic pesticides. The amount of obsolete pesticides among smallholder farming households adds considerably to the

Table 3. Summary of visual observation of 10 pesticide retail stores in Bolivia

	Yes (*n*/10)	No (*n*/10)	Missing (*n*/10)
Infrastructure			
Has sanitary services (bathroom/shower/etc.)	5	5	
Spacious store	2	7	1
Well ventilated area	2	8	
Has a cement floor (impermeable to liquids)	8	0	2
Has a first-aid kit	7	3	
Has absorbent material in case of a pesticide spill (sawdust, dirt, sand)	6	3	1
Pesticides are stored on shelves or pallets	10	0	
The shelves are metal	8	2	
The fertilizers, seeds, animal feed and veterinary products are stored next to the pesticide products	7	3	
The products are separated according to their level of flammability and biologic action (insecticides, herbicides, fungicides)	4	6	
If the products are not separated, the most toxic should be on the bottom and the liquids below the powders/dusts	1	5	4
The store is at more than 60% capacity	7	1	2
The sale and storage areas are separate	7	3	
The sales counter is orderly	6	3	1
Has a fire extinguisher	1	9	
The store has a pesticide odour	9	1	
Has warning symbols or signs: no smoking, no lighting of matches, etc.	1	9	
Has means of communication (phone, radio, etc.)	9	1	
Located in an urban area	10	0	
Food is being sold within 25 m of the store	8	1	1
Food, drinks or medicine are sold next to pesticides	1	7	2
Personnel			
Have a permanent technical advisor	9	1	
Have a medical insurance	3	7	
Employees are trained in the handling of pesticides	8	2	
Have personal protective equipment (mask, safety goggles, gloves, etc.)	5	5	
Use personal protective equipment	4	6	
Get regular medical check-ups	2	8	
Minors work at the store	3	7	
Pesticides are sold to minors	1	9	

officially estimated amounts. If we assume that there is approximately 775,000 smallholder farming households in Bolivia (Ministerio de Desarollo Rural y Tierras, 2014), and that these farming households have about the same amounts and characteristics of pesticides stored, it would mean that roughly 232.5 tons of pesticides are stored on smallholder farms, of which 59.9% (139 tons) are obsolete. This calculation adds one third to the amount of 377 tons of pure obsolete pesticides already calculated by the Food and Agriculture Organization (FAO) and Servicio Nacional de Sanidad Agropecuaria e Inocuidad Alimentaria (SENASAG) (Food and Agriculture Organization of the United Nations, 2003, 2013). As the climate differs considerably in different parts of Bolivia, this estimate might be insecure, but even restricting the estimate to La Paz County with approximately 170.000 smallholders, it would still add a considerable amount of obsolete pesticides on top of what has been estimated from the official dumping sites.

Table 4. Summary of visual observation of farmers' stocks of pesticides found in their homes and on their properties

Variable	Number (*N*)
Indicate active ingredient	278/312 (89.1%)
WHO class	
I = Highly hazardous	137/312 (43.9%)
II = Moderately hazardous	148/312 (47.4%)
III = Slightly hazardous	3/312 (1%)
U = Unlikely to present acute hazards	12/312 (3.8%)
O = Obsolete	12/312 (3.8%)
Chemical class	
Organophosphates (OP)	153/312 (49%)
Pyretheroids (PY)	125/312 (40.1%)
Carbamates (C)	9/312 (2.9%)
Organochlorides (OC)	2/312 (0.6%)
Others	23/312 (7.4%)
Lack an intact label	57/310 (14.8%)
Not stored in original container	44/312 (10.9%)
Lack Ministry of agriculture stamp	116/312 (37.2%)
Do not show expiry date	125/312 (40.1%)
Expired pesticides on the containers with expiry dates	15/187 (8%)
Illegal pesticide	39/312 (12.5%)
Storage of pesticides	
Store pesticides unlocked	1008/191 (56.5%)
In reach of children's	94/181 (54.5%)
Beside food	2/186 (1%)

The accumulation of obsolete pesticides has several causes according to the FAO, where commercial interests are mentioned among others (Food and Agriculture Organization of the United Nations, 1995). As part of these interests, the pesticide retailer has a central role in promoting the buying of pesticides in larger quantities (Food and Agriculture Organization of the United Nations, 1999). This contributes to the accumulation of pesticides at the end user. On country level, an excessive amount of imports and donations has been crucial in the stockpiling of pesticides in Bolivia and the amounts of obsolete pesticide stocks are yet increasing (Food and Agriculture Organization of the United Nations, 2003, 2013). Lack of staff trained in storage management has also been suggested as one of the reasons for the accumulation of obsolete pesticides (Aqiel Dalvie et al., 2006). It is also interesting to point out that even though pesticide retailers do not sell banned pesticides, illegal pesticides are found in the farmers' stockrooms and are somehow circulating and being sold in an illegal fashion. In fact, more than a third of all the pesticide found in the farmers personal inventories lacked a Ministry of Agriculture stamp (Table 4). These pesticides could also be remnants from old country stocks, which are being repackaged and resold.

As can be seen from the results section, the most frequently sold pesticides belong to WHO toxicity class II and I, corresponding to what we observed in the farmers' own stockrooms (Table 4). Similar observations were made in a Chinese study on small-scale farmers, where over 85% of the subjects claimed to use illegal pesticides (Yang et al., 2014).

The observational visits to the retail stores showed that many of the stores lack basic safety and sanitary measures, such as fire extinguishers, bathrooms and proper ventilation. Unsafe, contaminated and overly packed pesticide stores appear to be commonplace in many low-income countries to varying degrees. A South-African study from 2006 described comparable figures, where unwanted pesticides were being mixed with the ones being used, and where a majority of the surveyed pesticide stores had obvious spillings on the floors (Aqiel Dalvie et al., 2006). Other research in developing nations points in the same direction (Stadlinger et al., 2013).

As previously mentioned, pesticide retailers are a rarely studied group in scientific research. Despite that, they seem to play a vital role in the spread of information about pesticide handling to the local community. This is exemplified in the questions about the utilization of advice from the retailer when one determines which pesticide to use, as well as receiving advice from the pesticide retailer during the purchase itself (Table 2). Local customs and word of mouth seem to be the preferred methods when choosing a pesticide. This phenomenon is emphasized in a Caribbean study from 2005, were pesticide retailers were asked whether or not buyers seek their advice when buying pesticides. The study reported that 9 out of 10 retailers said customers requested their advice on precautions for use and storage of pesticides, and an absolute majority reported that customers asked about management of accidental exposure or ingestion of these agents (Pereira et al., 2007). The data we have so far on knowledge and practice when handling pesticides, does however not support the notion that the pesticide retailer is much more knowledgeable than the farmer.

Another negative trend observed in the present study is the unsafe storing of pesticides among the study population of farmers, where a majority reported keeping their pesticides unlocked and thus easily accessible to children and young adults. In Bolivia, self-poisoning with pesticides is the leading method for committing suicidal attempts and is most numerous among adolescents (Jørs et al., 2014). Other studies have documented an increased risk of suicides with exposure to pesticides postulating that not only is this increased risk caused by easy accessibility, but also that low-grade pesticide exposure in itself causes depression and mood disorders, thus increasing the risk of suicides (Meyer et al., 2010; Parrón et al., 1996). It is also common for farmers to store the pesticides outdoors or even inside their own residences (Table 4). This unsafe storing might explain the high number of suicidal attempts and accidental poisonings reported by the farmers in their villages.

The possibility of non-response and selection bias due to the simplicity of the study design and sampling method must be taken into consideration when analysing the data and interpreting the results. Since most of the pesticide retailers were recruited at a pesticide safety workshop as volunteers, they may be more aware of and interested in pesticide safety than the average retailer. Thus, the outcome for the whole region could be even worse than what the present study suggests. Moreover, information bias may have affected the reports on handwashing and PPE use, since the visual observations performed at the 10 pesticide stores showed that half of the surveyed stores lacked sanitary services and only half of them had PPE available on site. It is, therefore, improbable that the percentages on handwashing and PPE use are correct.

The strength of the present study lies in the fact that data were collected using both questionnaires as well as observational visits to the study sites. Direct visits on site adds another perspective, and can spot mismatch between the reporting of the subjects and the observations made at site, as seen in the previously mentioned reports of PPE.

In spite of this being a very simple study, mainly based on descriptive analysis, we hope that the results of this study together with other research from the area may benefit in the attempt to reduce malpractices in pesticide handling, primarily in Bolivia, but also in surrounding regions.

5. Conclusion

The study shows limited knowledge on pesticides safety measures and use of PPE, both among pesticide retailers and farmers. The very toxic WHO class I and II pesticides were found sold by the retailers and stored in the farmers homes. Sixty per cent of the pesticides found among the farmers were obsolete and an estimation of the accumulated amounts of obsolete pesticides that exist outside of the officially recognized dumping sites showed figures that exceed previous estimates by FAO and SENASAG. This underlines the necessity of including the small but numerous amounts of pesticides stored on farms, when calculating the total sum of obsolete pesticides in a country that needs to be gathered and destroyed. Moreover, the little knowledge on safe pesticide handling among the retailers need to be addressed as information from the retailers often are the only guidance farmers have to safer pesticide use and alternatives. In conclusion, better regulations of imports, sale and use of pesticides needs to be addressed by the government and other responsible parties.

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Appendix A

Pesticide store checklist

Checklist	**Fecha: Nombre de tienda**		
	Sí	No	Observaciones
A. Infraestructura de comercialización			
1. Cuenta con servicios sanitarios (baños, duchas, etc.)			
2. Local amplio			
3. Local ventilado			
4. Tiene piso impermeable a líquidos (piso de cemento)			
5. Hay muros completos			
6. Cuenta con botiquín de primero auxilios			
7. Posee material absorbente en caso de derramamiento de plaguicidas (aserrin, tierra, arena)			
8. Los plaguicidas están almacenados en estantes o palets			
9. Los estantes son metálicos			
10. Estan guardados fertilizantes, semillas, forrajes y/o productos de aplicación veterinaria junto con los productos fitosanitarios.			
11. Estan separados los productos por su grado de inflamabilidad y accion biológica (insecticidas, herbicidas, fungicidas)			

(*Continued*)

Appendix A (*Continued*)

Checklist	Fecha: Nombre de tienda		
12. Si los productos no están separados, los mas toxicos deben estar abajo y los liquidos debajo de los polvos			
13. La tienda esta mas del 60% de su capacidad de almacenamiento			
14. Están separados los sitios de expendio y de deposito			
15. El almacen de expendio es ordenado			
16. Cuenta con extintor			
17. Se siente olor a plaguicidas			
18. Tienen simbolos a letreros de advertencia: No fumar, no encender estufas, etc.			
19. Hay medios de comunicación (teléfono, radio, etc.)			
20. Está ubicada en una área urbana			
21. Existe venta de alimentos a menos de 25 m de distancia			
22. Si venden alimentos, bebidas o medicamentos estan al lado de los plaguicidas			
B. Del personal			
23. Cuenta con un asesor técnico permanente			
24. Tienen seguro médico			
25. El personal es capacitado en el manejo de plaguicidas			
26. Posee equipo de seguridad (máscara, lentes, guantes, etc.)			
27. Se usa el equipo de seguridad			
28. Se someten a chequeos médicos frecuentes			
29. Existen menores de edad en el local de expendio			
30. Se venden plaguicidas a menores de edad			

Chapter 6

What is the effect of training Bolivian small-holder farmers on Integrated Pest Management in terms of pesticide use, personal protection and the frequency of acute pesticide poisonings?

In this chapter a summary of the results from the survey no. 2 and the paper in its full length is presented.

6.1 Summary of results

Training farmers IPM significantly improved their performance from 2002 to 2009 on all variables on knowledge of pesticide toxicity, knowledge and use of organic methods, use of personal protection and safer handling of pesticides.

The same picture was seen among the neighboring farmers although not as many variables showed a significant or as big an improvement as among the trained farmers.

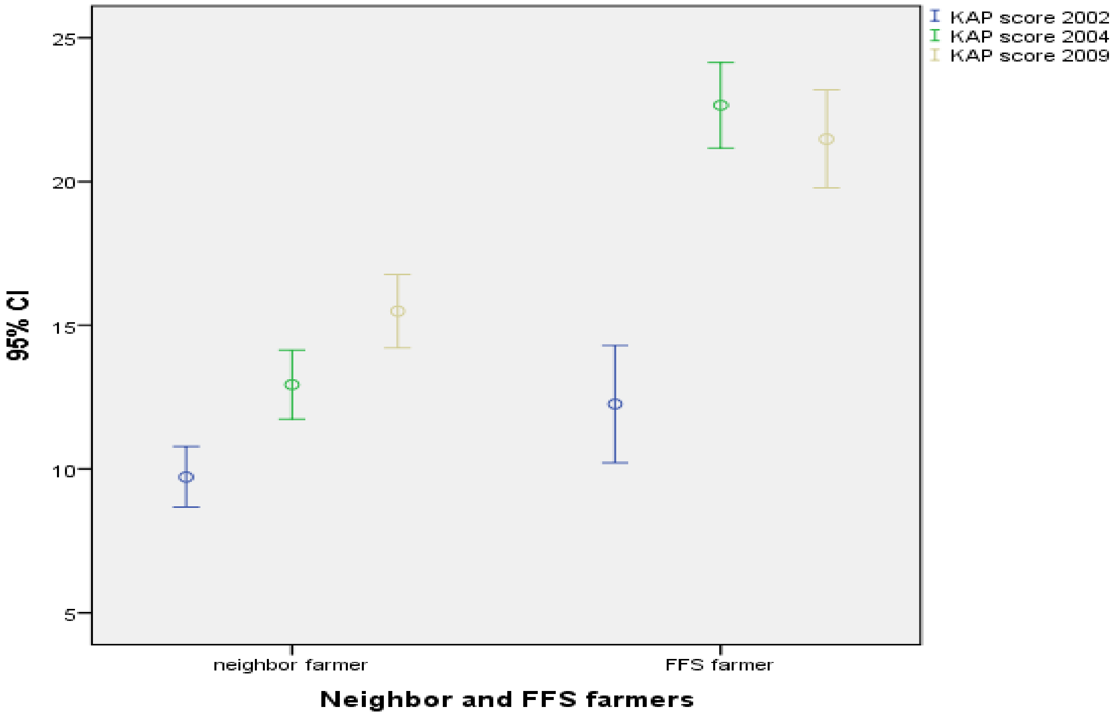
Organic farming increased most markedly among the IPM trained farmers where 12/40 (30%) changed to pure organic farming compared to their neighboring farmers where 12/89 (13.5%) changed.

A decrease in the number of self-reported APPs after spraying past year was seen from 18/23 (73.9%) in 2002 to 6/22 (27.3%) in 2009 among trained farmers and from 34/46 (73.9%) to 21/46 (45.7%) among neighboring farmers. For self-reported APPs after spraying the past months the reduction was also largest among the trained farmers (11/23 (49.8%) decreasing to 5/22 (22.7%)) while no significant change was seen among neighboring farmers.

An aggregated score on knowledge, attitude and practice (KAP-score) when handling pesticides was created. This KAP score showed that the trained farmers improved during their training period from a mean score of 12.26 (95% CI 10.22-14.30) out of a maximum of 27 in 2002 to a mean score of 22.65 (95% CI 21.16-24.14) in 2004 and then maintained their performance level 5 years after the training stopped. The neighboring farmers improved steadily from 2002 to 2009 with a mean score of 9.72 (95% CI 8.67-10.78) in 2002 to a mean score 15.49 (95% CI 14.21-16.77) in 2009.

See figure 6 below.

Fig 6 Changes in an aggregated score of variables expressing a potential risk of pesticide exposure among IPM trained farmers (N=23) and their neighboring farmers (N=47). Mean score and 95% CI presented for 2002, 2004 and 2009; maximum score = 27 – the higher the value the lower the potential risk of pesticide exposure.



FFS-farmers = IPM trained farmers on Farmer Fields Schools

6.2 Paper 2: "Do Bolivian small-holder farmers improve and retain knowledge to reduce occupational pesticide poisonings after training on Integrated Pest Management?"

ENVIRONMENTAL HEALTH

RESEARCH Open Access

Do Bolivian small holder farmers improve and retain knowledge to reduce occupational pesticide poisonings after training on Integrated Pest Management?

Erik Jørs[1*], Flemming Lander[2], Omar Huici[3], Rafael Cervantes Morant[3], Gabriel Gulis[4] and Flemming Konradsen[5]

Abstract

Background: Pesticide consumption is increasing in Bolivia as well as pest resistance, pesticide poisonings and pollution of the environment. This survey evaluates the training of small holder farmers on pesticide handling and ecological alternatives to reduce the negative pesticide effects.

Method: A baseline survey was performed in 2002 and follow-up surveys in 2004 and 2009. Farmers were selected and trained on Integrated Pest Management (IPM) from 2002 to 2004 in Farmer Field Schools (FFS). After exclusions and drop outs, 23 FFS trained farmers could be compared to 47 neighbor farmers for changes in 'knowledge, attitude and practice' (KAP) on IPM and symptoms of poisoning when handling pesticides. Statistical analysis was performed with SPSS version 21.0 using χ^2-test, Cochran's Q test and Student's T-test.

Results: Improvements were seen in both groups but most significant among the FFS farmers. At baseline no difference were seen between the two groups apart from a more frequent use of personal protection among the FFS farmers. After the training was finished significant differences were seen between FFS farmers and neighbor farmers on all KAP variables, a difference reduced to six of the KAP variables in 2009. No difference was seen in self-reported poisonings after pesticide handling. FFS farmers improved their KAP scores markedly during training and there after retained their knowledge, while neighbor farmers improved during the entire period. Ecological farming without the use of pesticides increased most among the FFS farmers.

Conclusion: The study showed a sustained improvement among Farmers Field School trained farmers on personal protection and hygiene when handling pesticides, knowledge and use of IPM and ecological alternatives and a reduction in self-reported symptoms after pesticide handling. Similar though less pronounced improvements was seen among neighbor farmers having had less training and information on pesticide handling and alternatives than the FFS trained farmers. Training of farmers on IPM and good agricultural practices has positive effects, but is scarce in Bolivia as in most low-income countries and must be encouraged to support an improved and sustainable food production and to protect the health of farmers and consumers as well as the environment.

Keywords: Pesticide poisoning, Farmers Field School, IPM, Sustainability, Bolivia

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Introduction

Pesticide consumption in low-income countries is rapidly increasing, as well as pest resistance, acute pesticide poisonings and environmental pollution due to improper and unsafe handling. To address this Farmers Field Schools (FFS) with training of small holder rice farmers on Integrated Pest Management (IPM), were introduced by the United Nations Food and Agricultural Organization (FAO) in Asia around 1990 [1-3]. Later the FFS were spread to other parts of the world, and to include other types of crops, livestock, health issues, water and sanitation and democracy [4-7]. The FFS concept promotes local solutions to local problems and uses participatory adult training processes and 'learning by doing' in the fields [1-3]. IPM is not uniformly defined but most often emphasizes the growth of a healthy crop with minimal disruption to agro-ecosystems [2,3,8]. IPM encourages natural pest control mechanisms keeping pesticides and other interventions to reasonable economic levels while reducing health and environmental risks [2,3,8]. The FFS concept have shown promising results among trained farmers most often by increasing yields and reducing pesticide use [1-7,9-17]. Some surveys have pointed to a possible broader effect by empowering participants improving their ability to plan, organize, take leadership and realize collective experiments [1-3]. Some studies have also focused on health and environmental outcomes when reducing and improving pesticide use and handling [1,4,14,15].

In Bolivia pesticide use has tripled over the last decade leading to a growing problem of acute poisonings due to accidents, suicides, and improper handling in agriculture and public health vector control programs [18-20]. One study showed improved technical handling of pests in potatoes after training farmers in FFS, on village workshops and through short messages in the radio [21].

This survey presents the effects of training a cohort of small holder farmers from 2002 to 2004 with follow-up studies in 2004 and 2009. The objective was to show if FFS training would have long term impact on farmers knowledge, attitude and practice (KAP) to improve the handling of pesticides using IPM strategies and to lower the number self-reported symptoms of acute poisoning after pesticide handling.

Methods

Study area and population

The Plagbol project was launched in 2001 and continued until 2013 promoting training, information and awareness rising among farmers, health care workers, teachers and pre-graduates to prevent pesticide poisonings and environmental pollution. The training activities of the first project phase from 2001 to 2004 were implemented in four municipalities within the La Paz County. This is an area with varying climates, from temperate to subtropical, making it possible to grow a wide variety of crops. Most pesticide spraying takes place from October to May.

Farmers Field School training was offered to 48 hamlets/small villages known to have a significant use of pesticides and good accessibility by road or river with a total population of around 10.000 people (pers com Plagbol Project). Local authorities and farmers were extensively involved in the selection of hamlets, selection of the farmers for FFS training and later planning and execution of the trainings to create local ownership and improve sustainability of the interventions.

Criteria taken into consideration in the selection of the farmers were 'a person of confidence', 'ability to read and write' and 'permanent residence in the hamlets' to maintain the trained human resources in the area. FFS trainings took place in the different hamlets to enable the rest of the villagers to follow the courses when they took place in their hamlet.

Intervention

The FFS farmers were trained in IPM methods to improve their Knowledge Attitude and Practice (KAP) concerning pesticide handling and ecological farming methods during 14 theoretical and practical courses of one to two days duration. After having completed at least 12 of the courses the farmers were given a diploma as an FFS farmer. The intensive training courses took place over a period of 20 month from June 2002 to February 2004. Educational booklets for the seven theoretical modules were developed by the project agronomist and doctor on: 1. Pedagogic, 2. The World of Pesticides, 3. The Use of Pesticides, 4. Agricultural Pests, 5. Health Effects of Pesticides, 6. IPM Methods and 7. IPM in Tomatoes [22]. A draft version of the booklets was used for each training course and then modified according to the input from the farmers and project supporters before been printed in a final version for distribution among the farmers.

A minimum of two courses on 'Integrated Pest Management' and 'Adequate use of pesticides', were undertaken in the hamlets by the FFS farmers to train their neighbor farmers as well as informal knowledge sharing taking place on a day to day basis. To facilitate dissemination from FFS farmers to neighbor farmers the first module was on pedagogy. During the FFS training the farmers produced their own teaching material such as flipcharts, herbarium and insect collections to be used for teaching sessions in their hamlets, and rehearsed by teaching each other.

To improve awareness in the general population, radio and television programs were transmitted and informative pamphlets, folders and copies of the training materials were distributed through the internet and as hard copies.

Study design

A baseline survey was conducted among 201 farmers from March to April 2002 before the selection of the farmers to go for FFS trainings took place. From this baseline 40 FFS farmers, out of 60 FFS trained farmers, could be identified and included in the first follow-up survey taking place from October to November 2004. It was decided to include twice as many neighbor farmers from the baseline study. They were invited at meetings in the hamlets and via 'mouth to mouth method' to show up at a central place in the hamlets at a given date and time. Eighty nine neighbor farmers showed up and were interviewed in their villages together with the FFS farmers.

Due to a very skewed gender distribution in the two groups of farmers it was decided to exclude female farmers from the main analysis to avoid gender bias as a former study did show significant differences between Bolivian male and female farmers regarding pesticide handling and symptoms [23]. The farmers who shifted to ecological farming were also excluded from the main analysis as most of the questions about classes of pesticides used, personal protection and hygiene while handling pesticides and symptoms of pesticide intoxications were irrelevant to this group. Then there were some drop outs mainly due to migration. We ended up with 23 FFS farmers and 47 neighbor farmers with a full data set for the main analysis comparing data from 2002, 2004 and 2009, see flow chart Figure 1.

The survey was approved by the Medical Ethical Committee of Bolivia, and all participants signed an informed consent form before the interviews were conducted.

The survey was based on a pre-tested questionnaire developed for the 2002 baseline study using interview forms developed in former studies from Bolivia, Denmark and the US [24]. The questionnaire consisted of closed and open-ended questions, including age, sex, education, size of cultivated land, crops cultivated, pesticides and alternatives used, knowledge, attitudes and practice when buying, handling and storing pesticides; perceived negative impact from pesticides; and own experience with poisoning after handling pesticides. The interviews were conducted by trained Spanish speaking health care workers, agronomists and students. The follow-up surveys compared changes within and between the two groups of farmers.

The outcome variables are all dichotomous variables. The variable 'use of WHO class I pesticide' was elaborated from a question about which pesticides the farmers were using and then the pesticides were categorized into the different WHO toxicity classes.

Three of the variables analyzed are aggregated variables with each variable included given equal weight and then dichotomized. The use of aggregated variables was preferred to be able to present as much information as possible in the analysis, and one can argue that aggregated variables may provide a better overall picture of the type of exposure and the association with outcome, resulting in a more robust analysis.

The variable 'Personal protection' was aggregated from the variables 'using long sleeved shirts when spraying', 'using long trousers when spraying', 'using a hat when spraying', 'using a mask when spraying', 'using gloves when spraying', 'using boots when spraying', 'washing body after spraying', 'changing clothes after spraying', and 'refraining from eating, chewing coca or smoking while spraying'. The aggregated variable was dichotomized according to positive answers to at least 6 of the 9 variables.

The variable 'Good technical handling' was aggregated from the variables 'adjusting sprayer before spraying', 'washing sprayer after spraying', 'refraining from spraying same day as harvest', 'no re-entry into the field the same day as spraying', 'burning/burying empty pesticide containers', 'storing pesticides locked up'. The variable was dichotomized according to positive answers to at least 4 of the 6 variables.

The variable 'Knowledge of pesticide toxicity' was aggregated from the variables 'do you think pesticides can have negative effects on human health', 'do you think pesticides can have negative effects on animal health', 'do you think pesticides can have negative effects on the environment', 'can you mention two or more symptoms of pesticide poisoning', 'knowing that red color on pesticide container means highest toxicity' and 'knowing that green color on pesticide container means low toxicity'. The variable was dichotomized according to correct answers to at least 5 of the 6 variables.

To give an overview of performance in the two groups and its development through the years 2002, 2004 and 2009 an error bar graph with 95% CI was elaborated calculating a mean KAP score for each year. The KAP score was created by aggregating all of the 27 KAP variables and giving all variables the same weight the maximum KAP score was 27.

Data analysis

The non-parametrical Cochran's Q test for k related samples were used for changes in KAP-variables and symptoms within each group of farmers over the whole period 2002 to 2009.

Mc'Nemar's test for paired samples was used to compare difference within each farmers group in the two periods 2002–04 and 2004–09.

χ^2 test were used to compare differences between the two groups of farmers at baseline and at each follow up.

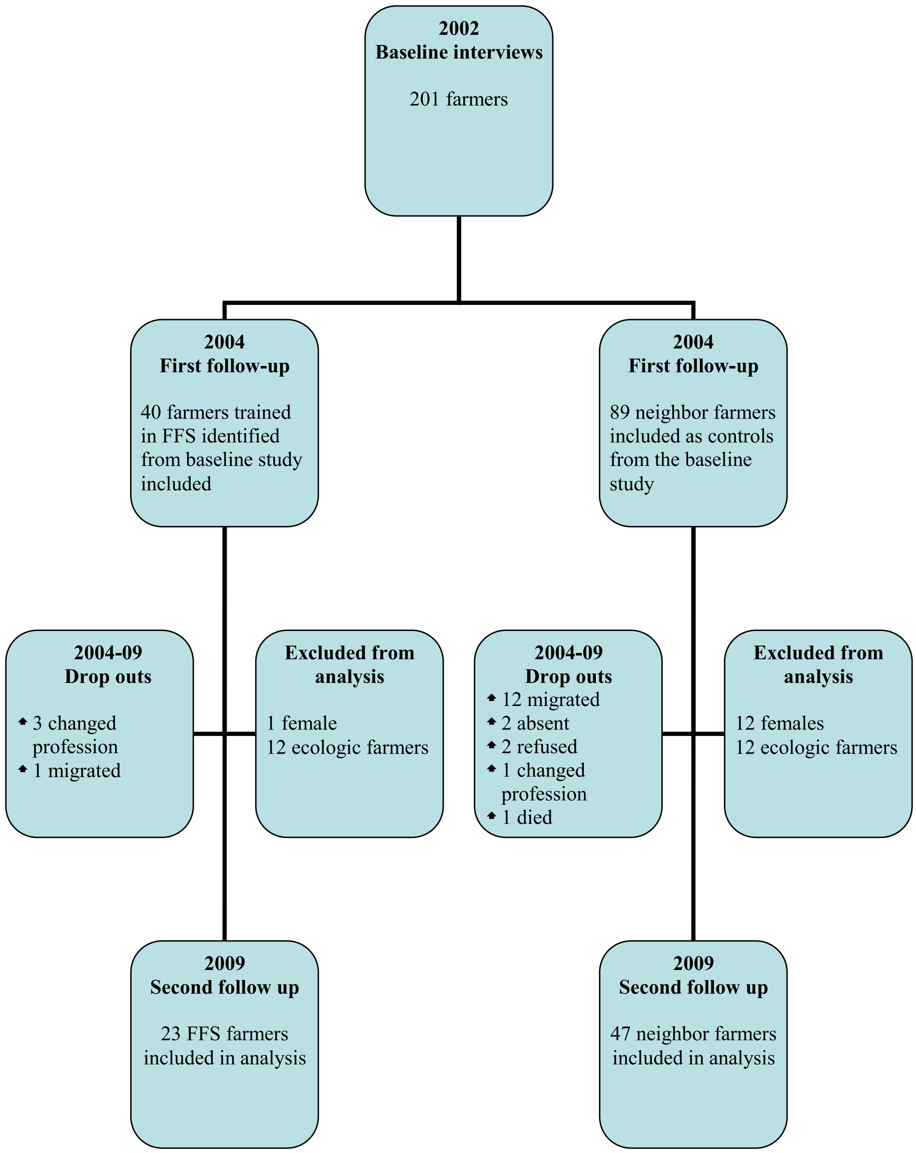

Figure 1 Flow chart of study participants.

T-test were used for calculating age, years in farming, size of land cultivated and for calculating mean KAP-score with 95% CI.

Missing values were kept missing. The analysis was conducted with SPSS version 21.0.

Results

General data

A significant difference between the two groups was found for age and years working as a farmer (Table 1). FFS farmers cultivated more land and were better educated than their neighbor farmers, although these differences were not significant. Comparing age and farming years it was seen that the typical time for starting to farm as a profession was around 16 years of age.

Comparing participating farmers with excluded farmers and drop outs no significant differences were found between the two groups on the general variables, KAP variables or symptoms of poisoning after spraying.

Effect of the intervention within FFS farmers and neighbor farmers

Analyzing the changes from 2002 to 2009 within each of the two groups of farmers with Cochran's test all variables improved significantly among the FFS farmers, while 6 significant improvements and one borderline improvement were seen in the group of neighbor farmers (Table 2).

Analyzing each of the two periods 2002–04 and 2004–09 the FFS farmers had improved by far the most at the

Table 1 General data at baseline 2002 among FFS farmers (N = 23) and neighbor farmers (N = 47)

Variables		Mean	Range	p-value
Age, mean	FFS farmers	34,6	22-61	0.01
	Neighbor farmers	42,6	19- 70	
Years in farming, mean	FFS farmers	19,1	1-40	0.03
	Neighbor farmers	26,2	3-60	
Hectares grown, mean	FFS farmers	2,1	0,2-15,1	0.06
	Neighbor farmers	1,1	0-4,5	
		%		
Farming in temperate climate	FFS farmers	65,2		0.81
	Neighbor farmers	68,1		
Educational level above primary school	FFS farmers	73,9		0.08
	Neighbor farmers	52,2		
Received course on pesticide handling	FFS farmers	26,1		0.51
	Neighbor farmers	19,1		

χ^2-test and Student's T-test used for calculating p-values.

first follow up in 2004 where Mc'Nemar's test for paired data showed significant improvements ($p < 0.05$) in 10 of the 11 variables with the exception being the variable on 'number of times sprayed past month'. The neighbor farmers showed improvement in 6 of the 11 variables including all 'personal security measures' and 'pesticide toxicity and intoxication' variables except for the variable on good personal protection ($p < 0.05$). From 2004 to 2009 no significant changes were seen among the FFS farmers, while the neighbor farmers still improved significantly, as the variables 'No use of pesticide WHO class 1', 'Knowledge of alternatives to pesticide use' and 'Good personal protection when handling pesticides' became significant ($p < 0.05$), while the variables 'Good technical handling' and Good knowledge of pesticide toxicity' became borderline significant ($p < 0.10$) and 'No self-reported symptoms after spraying past month became non-significant ($p > 0.05$) changing from being significant at first follow up.

In Figure 2 the change is illustrated in a graph showing that the FFS farmers almost doubled their mean KAP-score during their intensive training period from 2002 to 2004 with no further improvement there after while the neighbor farmers showed a steadier but less pronounced improvement through the whole period from 2002 to 2009.

Comparison of the intervention effect between the FFS farmers and the neighbor farmers

At baseline in 2002 only the aggregated variable 'good personal protection' showed a significant difference between the FFS farmers and neighbor farmers (χ^2-test, $p < 0.05$), see Table 1. In 2004 the χ^2-test showed significant differences between the two groups in all the KAP variables, and in 2009 the number of variables with significant differences between the two groups was reduced from nine to six, (Table 2).

To evaluate a possible influence on KAP variables by age, education, years in farming, size of land cultivated and climate a stratified analysis was done. The only significant findings were that farmers from the subtropical climate showed a better performance on the variables 'Refrain from blowing nozzle when obstructed', 'Good personal protection', 'Good technical handling' and 'Good knowledge of pesticide toxicity'. This might be explained by the finding that the farmers who had received courses on pesticide handling from pesticide retailers and others before project start in 2002 were primarily farmers living in the subtropical versus the temperate climate ($p < 0.05$).

Ecological farming

Twelve of the initial 40 FFS farmers (30%) and 12 of 89 neighbor farmers (13.5%) changed to ecological farming (χ^2-test $p < 0.00$). All FFS farmers improved their knowledge on alternative ecological farming methods with an increase in the mean number of mentioned pest controlling methods from 0.3 to 2.4 per farmer, compared to the conventional farmers, 0.2 to 0.4 methods per farmer. The methods reported were light and color traps for attracting and killing insects and different plant extracts used for making natural pesticides for spraying on the crops.

Farmers who tried to practice ecological farming were more likely to be farmers from the subtropical climate 23/56 (41.1%) compared to 7/73 (9.6%) of the farmers from the temperate climate (χ^2-test $p < 0.00$).

Discussion

The survey showed significant improvement in pesticide handling and use of alternatives to pesticides among

Table 2 KAP variables and symptoms of intoxication among FFS farmers and neighbor farmers from 2002-04-09

Categories/Variables	Farmer groups	2002 χ^2-test		2004 χ^2-test		2009 χ^2-test		2002-04-09 Cochran's test
		N (%)	p-value	N (%)	p-value	N (%)	p-value	p-value
No use of WHO class I pesticides	FFS farmers	3/23 (13)	0.67	16/23 (69.6)	0.00	17/23 (73.9)	0.07	0.00
	Neighbor Farmers	8/47 (17)		12/47 (25.5)		24/47 (51.1)		0.00
Have sprayed less than three times past month	FFS farmers	12/23 (52.2)	0.10	18/23 (78.3)	0.00	16/23 (69.6)	0.07	0.04
	Neighbor Farmers	15/47 (31.9)		17/23 (36.2)		22/47 (46.8)		0.28
Think pesticide use can be lowered without affecting harvest	FFS farmers	7/23 (30.4)	0.70	20/23 (87)	0.00	17/23 (73.9)	0.01	0.00
	Neighbor Farmers	12/46 (26.1)		16/47 (34)		20/47 (42.6)		0.27
Knows alternative methods to pesticide use	FFS farmers	4/23 (17.4)	0.43	22/23 (95,7)	0.00	23/23 (100)	0.00	0.00
	Neighbor Farmers	5/47 (10.6)		10/47 (21,3)		15/47 (31.9)		0.22
Reads instructions on pesticide container before use	FFS farmers	7/23 (30.4)	0.85	23/23 (100)	0.01	22/23 (95.7)	0.26	0.00
	Neighbor Farmers	13/46 (28.3)		34/46 (73.9)		40/46 (87.0)		0.00
Refrain from blowing spray-head when obstructed	FFS farmers	12/23 (52.2)	0.47	23/23 (100)	0.00	21/22 (95.5)	0.04	0.00
	Neighbor Farmers	18/42 (42.9)		33/47 (70.2)		35/47 (74.5)		0.00
'Good personal protection' (aggregated variable)	FFS farmers	8/23 (34.8)	0.03	19/22 (86.4)	0.00	18/21 (85.7)	0.00	0.00
	Neighbor Farmers	6/46 (13.0)		6/47 (13)		20/45 (44.4)		0.00
'Good technical handling' (aggregated variable)	FFS farmers	5/22 (22.7)	0.63	19/22 (86.4)	0.00	16/20 (80)	0.00	0.00
	Neighbor Farmers	8/45 (17.8)		21/42 (50)		15/41 (36.6)		0.02
'Good knowledge of pesticide toxicity' (aggregated variable)	FFS farmers	7/23 (30.4)	0.31	22/23 (95.7)	0.00	21/23 (91.3)	0.00	0.00
	Neighbor Farmers	9/46 (19.6)		21/47 (44.7)		18/41 (43.9)		0.06
No self-reported symptoms after spraying past year	FFS farmers	6/23 (26.1)	1.00	14/23 (60,9)	0.54	16/22 (72.7)	0.15	0.00
	Neighbor Farmers	12/46 (26.1)		25/47 (53,2)		25/46 (54.3)		0.02
No self-reported symptoms after spraying past month	FFS farmers	12/23 (52.2)	0.61	20/23 (87)	0.31	17/22 (77.3)	0.43	0.01
	Neighbor Farmers	27/46 (58.7)		36/47 (76.6)		32/47 (68,1)		0.12

(χ^2-test used for calculating significant differences between the two farmers groups and Cochran's Q test for calculating significant differences within each farmers group).

farmers trained at farmer's field schools, an improvement that was maintained 5 years after the training stopped. The same though less profound was seen among the neighbor farmers, which could be due to dissemination of knowledge from FFS trained farmers in combination with diffusion of information into society by the Plagbol project. It could also simply be due to an improved knowledge level on IPM and good agricultural practices among Bolivian farmers in general. The intensively trained FFS farmers improved during their training period from 2002–04, while the neighbor farmers improved over the whole period, and never reached the higher 'KAP-score' of the FFS farmers, a difference probably reflecting the different training and information level in the two groups. A considerable number of farmers turned to ecological farming thereby reducing the negative effects on health and environment by pesticide use. The results must be interpreted with caution due to the limited number of participants and the lack of a control group without influence by the project interventions.

In the selection of farmers we saw that farmers tended to select the better educated and younger men to go for trainings. This experience must be taken into account when starting similar FFS trainings with the aim to include more women and resource poorer farmers in the trainings. The selection of literate farmers was though promoted by the project to improve the chances of having a positive effect of the trainings. This has also been seen in other studies showing skewed age, education, social level and gender distribution among the FFS participants [6,7,12,25].

An improved pesticide handling and use of IPM methods among FFS trained farmers has been shown in several other studies [1-4,6,7,9,12,13,15-17,21,25,26]. Some studies found the acquired knowledge and positive results were retained, although evaluated over a shorter time period than in the actual study [1,4,6,12]. This is though questioned by others finding some of the positive results were lost over time [11]. Supporting possible sustainability of the FFS trained farmers is the finding in a later evaluation of the Plagbol project from

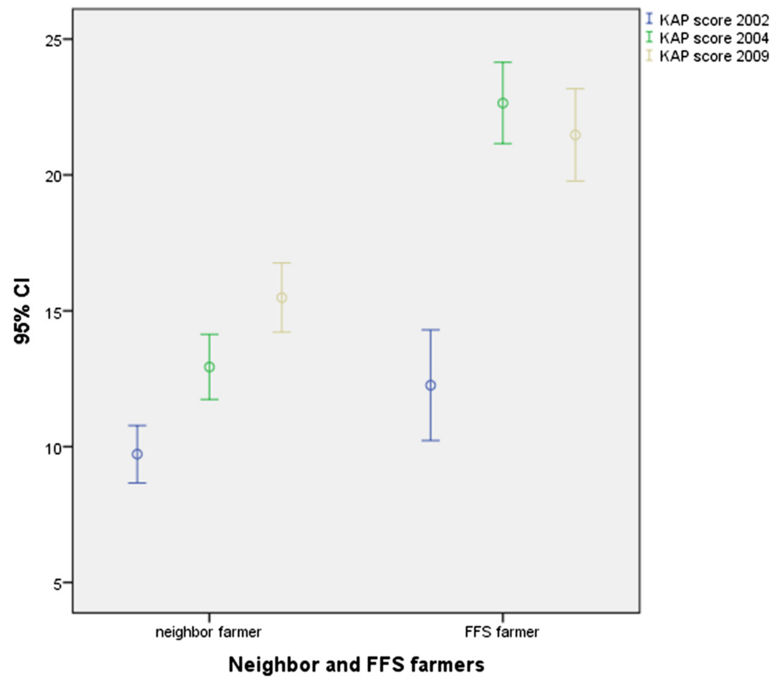

Figure 2 Changes in KAP score of FFS farmers (N = 23) and neighbor farmers (N = 47) from 2002 to 2004 to 2009, mean values with 95% CI, (maximum score = 27).

2012 that FFS farmers are now recognized as specialists on crop protection and hired for training of farmers in other hamlets/villages by their Municipalities 8 years after their training have stopped [27].

Whether or not positive experiences in one place can be transferred to different crops, farming systems and cultures is debated and there is little doubt about the need for adaptation of the FFS concept and IPM training to local circumstances if success shall be expected [1,3,4,6,28,29]. An evaluation from 2013 in the Plagbol Project indeed points to this as farmers in Focus Group discussions mentioned ´that growing special crops like coffee and tee favored IPM and ecological farming as a demand for ecological products made the prices increase compared to the conventionally grown [30].

Our finding of a reduced number of farmers reporting the use of WHO class I pesticides could be a reflection of what is seen in other studies showing a significant reduction in pesticide use after FFS training [1-7,9-17,25]. The increase in yields shown in these studies as well is not necessarily linked to the reduction in pesticide use, but might as well be due to the 'good agricultural practices' taught alongside the use of alternatives to pesticides when teaching IPM in FFS, and as some pointed out IPM teaching should be renamed ICM (integrated crop management) as pest control implies a lot of other cultural practices apart from a correct and minimized pesticide handling and use [28].

The improved use of personal protective equipment (PPE) and hygiene have been seen in other intervention studies among FFS trained farmers as well [6,9,15,31]. A problem regarding the use of PPE in most low income countries is that good PPE is scarce, expensive and not comfortable to wear under hot tropical conditions [32]. A solution could be to focus on the cheapest, most simple and effective PPE measures like the use of gumboots, gloves and changing and washing long sleeved pant and shirt after spraying.

An important finding is the reduction in the number of farmers reporting poisoning symptoms after pesticide spraying which might be related to the improvement seen in the KAP variables, and especially in the two variables 'reading instructions for use' and 'refrain from blowing spray nozzle when obstructed', as they have been found to be independent risk factors for self-reported symptoms of pesticide poisoning and Acetylcholine-esterase depression [18]. The reduction of symptoms after spraying has been evaluated in other studies where an increase in the use of IPM methods and personal protection when handling pesticides seems to have resulted in fewer symptoms of poisoning and affection of the blood Acetyl Cholinesterase level [1,4,14,15].

Most often the economic aspect has been evaluated as an argument for adoption of IPM but to include health and environmental aspects as arguments for the adoption and diffusion of IPM is a possibility that should be explored. Farmers mention the importance of these aspects, not only the economical one when deciding whether or not to shift to IPM farming or ecological farming [30].

Weaknesses of the survey

The size of the study is a limitation, and made it difficult to use a controlled analysis due to the broad confidence intervals coming up. The farmers who participated in the trainings in the FFS were a selected group being younger and better educated than their neighbor farmers whom we used for comparison. A random selection of FFS farmers was not possible as the farmers selected among their own representatives to go for FFS training. For comparison of the effects of the training within the same group of farmers this was not a problem as the farmers were their own controls. When comparing the changes between the two groups an analysis controlling for age and education would have been desirable to minimize the possibility for confounding, although age and education were of no significance when analyzing KAP variables at baseline in 2002. Random selection is difficult to practice in most low-income countries as no updated population registers exists, most people are functional illiterate and a formal direction with road name and number to send mail to are not available. Neighbor farmers were therefore invited by direct oral communication at village meetings or if found at home when visiting the villages.

The use of self-reported symptoms when spraying pesticides might introduce recall bias as they are nonspecific and people might have difficulty in recalling them a whole year or even a month previously. Some groups with increased awareness (FFS farmers) and with major events (very sever poisoning episodes) might have longer recall than other groups and events.

A difference in climate and pest pressure at the different times of the data gathering is a problem influencing the number of sprayings and the chances of getting poisoned past month and must be taken into account when interpreting changes in these variables.

Studying information dissemination between farmers and their neighbors was not possible due to small numbers and lack of a control group without influences from the project interventions. In a future study including a control group or a possible network analysis exploring social capital dimensions and the use of mixed methods could be more appropriate to explore dissemination of knowledge as shown by others [9].

Conclusion

The study showed a sustained improvement among Farmers Field School trained Bolivian farmers on personal protection and hygiene when handling pesticides, knowledge and use of IPM and ecological alternatives and a reduction in self-reported symptoms after pesticide handling. Similar though less pronounced improvements was seen among neighbor farmers having had less training and information on pesticide handling and alternatives than the FFS trained farmers.

Training of farmers on IPM and good agricultural practices has positive effects, but is scarce in Bolivia as in most low-income countries and must be encouraged to support an improved and sustainable food production and to protect the health of farmers and consumers as well as the environment.

Competing interests

The authors declare that we have no competing interests.

Authors' contributions

EJ was the leader of the research. He contributed to all phases in the research project from conception and design, the acquisition and analysis of data and the writing of the manuscript. FL contributed to the conception and design, the acquisition of data and the revision of the manuscript for intellectual content. OH contributed to the conception, design and the acquisition of data. RCM contributed to the conception and design and the acquisition of data. GG contributed to the revision of the manuscript for intellectual content. FK contributed to the revision of the manuscript for intellectual content. All authors have given their final approval of the version to be published.

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Chapter 7

Can knowledge and practice of Integrated Pest Management be disseminated from trained Bolivian small-holder farmers to their neighboring farmers?

This chapter presents a summary of the results from the surveys no. 3 and 4 and the papers in their full length.

7.1 Summary of results

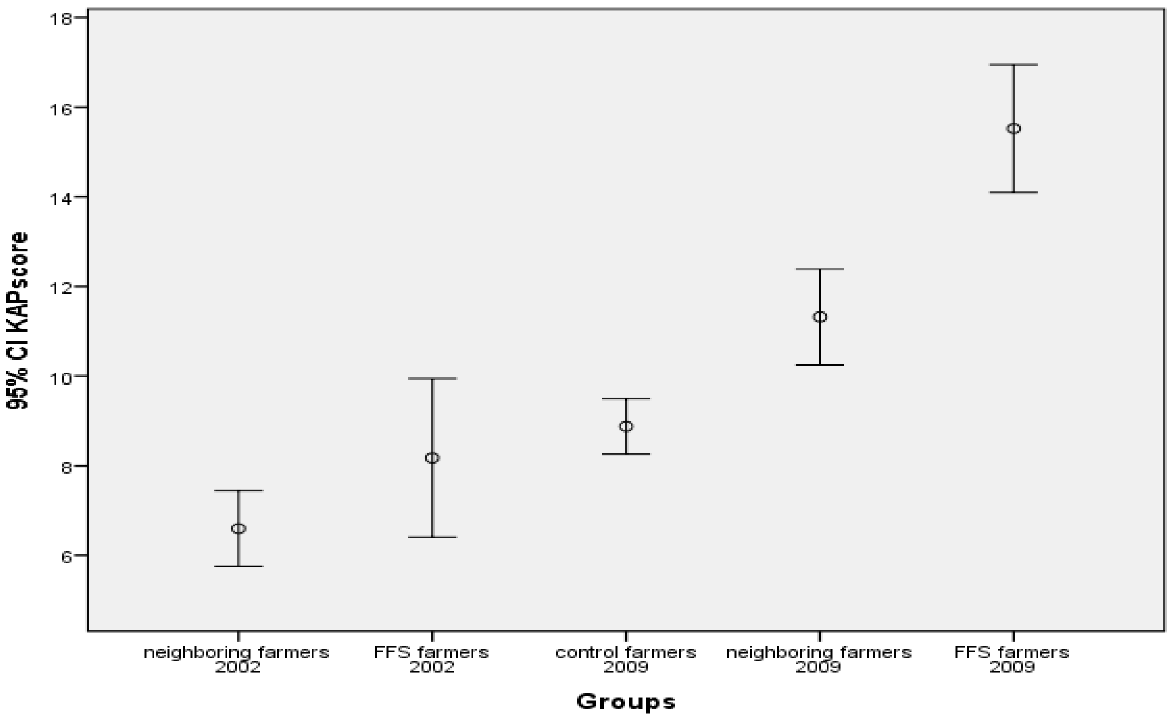
The cross-sectional survey from 2009 showed a higher knowledge of pesticide toxicity, use of personal protection and safe handling of pesticides both among IPM trained farmers and their neighboring farmers when compared to a control group of farmers from outside the intervention areas. This is summarized in an aggregated variable showing the KAP score of all three groups in 2009, and the KAP score of trained farmers and their neighboring farmers before the interventions started in 2002, see fig 7.

The qualitative survey with Focus Group discussions showed IPM farming being more laborious than conventional farming according to both farmers and agronomists. This extra labor was not always compensated for by higher net revenue when selling the products. The value of the harvest depended apparently on the type of product and nearby markets, as strawberry, coffee, tea and coca farmers found the value of their products higher than the same products grown with pesticides, while vegetables farmers did not get a higher market price for their products. Although many of the techniques resemble traditional farming techniques they are still judged as medium difficult to practice by the farmers.

In favor of IPM farming was the lower production costs, an easiness to try it out, a healthier and more environment-friendly farming methods in harmony with local culture , and the possibilities to make own experiments and local adaptions with IPM.

It was not found easy to create alliances in the local society to spread the IPM to other farmers and into the wider society.

Fig 7 Aggregated mean score on Knowledge, Attitude and Practice on IPM and pesticides among IPM trained farmers, their neighboring farmers and control farmers. Mean score and 95% CI presented; maximum score = 20 – the higher the value the lower the potential risk of pesticide exposure.



FFS-farmers = IPM trained farmers on Farmer Fields Schools

Note:

Neigboring farmers 2002 (N=47)	*mean 6.66*	*95% CI 5.81-7.51*
FFS farmers 2002 (N=23)	*mean 8.17*	*95% CI 6.41-9.94*
Control farmers 2009 (N=136)	*mean 9.18*	*95% CI 8.55-9.80*
Neigboring farmers 2009 (N=34)	*mean 11.97*	*95% CI 10.56-13.38*
FFS farmers 2009 (N=20)	*mean 16.55*	*95% CI 15.45-17.65*

7.2 Paper 3: "Can knowledge and practice of Integrated Pest Management be disseminated from trained Bolivian small-holder farmers to their neighboring farmers?"

7.3 Paper 4: "Obstacles and possibilities for diffusion of Integrated Pest Management strategies among Bolivian farmers!"

Paper 3

The impact of training Bolivian small-holder farmers on Integrated Pest Management and diffusion of knowledge to their neighboring farmers.

By: Jørs Erik, Konradsen Flemming, Huici Omar, Morant C Rafael, Volk Julie, Lander Flemming.

ABSTRACT

Background: *Teaching farmers Integrated Pest Management (IPM) in Farmer Field Schools (FFS) has led to reduced pesticide use and safer handling. This article evaluates the long term impact of training farmers on IPM and the diffusion of knowledge from trained farmers to neighboring farmers - a subject of importance to justify training costs and to promote a healthy and sustainable agriculture.*

Method: *Training on IPM of farmers took place from 2002 to 2004 in their villages in La Paz County, Bolivia, while dissemination of knowledge from trained farmer to neighboring farmer took place until 2009. To evaluate the impact of the intervention, the self-reported knowledge and practice on pesticides and IPM methods among trained farmers (N=23) and their neighboring farmers (N=47) were analyzed in a follow up study and compared in a cross-sectional analysis to a control group of farmers (N=138) introduced in 2009. Variables were analyzed using* χ^2*-test test and ANOVA. The study was approved by the Medical Ethical Committee in Bolivia.*

Results: *Trained farmers improved and performed significantly better than their neighboring farmers also improving performance from 2002 t0 2009. An increasing trend on IPM and pesticide handling were seen from control farmers, to neighboring farmers to trained farmers in most of the variables when compared on 2009 data. In an aggregated variable trained farmers (mean score 16.55, 95% CI 15.45-17.65) performed better than their neighboring farmers (mean score 11.97, 95% CI 10.56-13.38), who again performed better than the control farmers (mean score 9.18, 95% CI 8.55-9.80). Controlling for age and living altitude did not change these results.*

Conclusion: *Trained and neighboring farmers improved and maintained knowledge and practice on IPM and pesticide handling over the years. Diffusion of knowledge from trained farmers to neighboring farmers might explain the better performance of the neighboring farmers compared to the control farmers. Dissemination of knowledge can contribute to justify the cost and convince donors and governments in low income countries to prioritize farmers training.*

INTRODUCTION

Pesticide poisonings pose a serious threat to public health in middle- and low-income countries where most of the poisonings are seen due to the use of very toxic and easily available pesticides, (1-3). Three million severe acute pesticide poisonings was estimated at global level in 1990, of which 2 million was self-inflicted and 1 million was unintentional (1). The number of the less serious acute occupational pesticide poisonings was estimated to be 3% of the agricultural workers in the developing world resulting in 25 million cases annually based on surveys from Asia using self-reported data (1). The fatalities were estimated to be 220.000 of which the majority was due to self-poisoning (1). Estimates on the number of occupational pesticide poisonings have since 1990 mostly been made on regional, national or local field assessments and have shown acute pesticide poisonings varying from 7% to 88% among the interviewed farmers, and incidence rates of 17.8 to 35 per 100.000 in the general population (3-12). More recent estimates on self-harm by pesticides have shown from 1,291,170 to 2,582,340 cases annually of which 234.000 to 326.000 die (13). These numbers may be even bigger due to known underreporting and the lack a uniform definition of pesticide poisoning, wherefore the WHO has provided a guide to uniform classification of a pesticide poisoning case (3). Frequent acute poisonings can lead to chronic poisonings causing neurotoxic, repro-toxic, feto-toxic and carcinogenic effects (14-18).

To prevent poisonings, pest resistance and negative environment effects, training of farmers on Integrated Pest Management (IPM) in Farmer Field Schools (FFS) has been tried out in many parts of the world (19-22). IPM promotes ecological alternatives to pesticides, decreased use of pesticides, a better hygiene and the use of personal protective equipment when handling pesticides - factors shown to be of importance for poisonings (22-29).

Results from FFS trainings have shown an increased knowledge and use of IPM methods, a reduction in the use of pesticides and increased yield and/or profits among trained farmers (19-22, 24,30-32). Some studies have shown improved personal protection and hygiene for persons handling pesticides and fewer symptoms of intoxication after spraying (22,24-27,30), while others have failed to show these positive effects (33-35).

In spite of the IPM trainings, the strategy has not spread as hoped for, and pesticide use is still increasing, especially in middle and low-income countries (20,36,40). There is an obvious lack of investment for up-scaling and mainstreaming IPM, which may be due to a wish in many low income countries to boost their agriculture by introducing pesticides as the easiest and fastest way to effective pest control (22). Drivers for increased pesticide use include high pest incidences, *subsidies through package loans for seeds and pesticides, farmers' lack of knowledge of the economics of pest control and lobbying by pesticide companies (37-41). Common obstacles to IPM diffusion are found to be 'insufficient training and technical support to farmers', 'lack of favorable government policies and support', 'farmers' low level of education and literacy in low income countries', 'IPM too difficult practice' and 'a powerful influence of pesticide industry' (20,37,39,40,42,43). An important reason for the difficulties experienced in mainstreaming IPM in agriculture could be the lack of dissemination of knowledge from trained farmers to neighboring farmers (19-21,28,31,32,44-50).*

In a former study, we have shown that trained farmers improved their knowledge and practice regarding pesticide use and IPM methods, while their self-reported symptoms of pesticide poisoning decreased (30). The objective of the actual study is to evaluate the long term impact of training farmers and whether a diffusion of knowledge takes place from trained farmers to their neighboring farmers by comparing performance with a control group of farmers. This study can be a supplement to other studies from 'the Andes' in Latin America with a qualitative approach to the evaluation of IPM trainings (24,27,33,42,47,51).

METHODS

Study area

This study was undertaken as part of a development project to prevent pesticide poisonings, named the Plagbol project, launched in 2001 in La Paz County in Bolivia. The county has a population of approximately 2.7 million with an estimated 300.000 living in the rural areas as smallholder farmers. The landscape is mountainous and the climate varies from temperate to subtropical, often within a distance of a few kilometers, making it possible to grow a wide variety of crops such as vegetables, corn, potatoes, flowers, fruits, coffee and rice. This produce is marketed in the nearby capital, La Paz.

A baseline study and later follow-up were conducted in 2002 and 2009 in 20 villages among small-scale farmers trained by the project on IPM methods and their neighboring farmers. In order to compare performance a control group of farmers was included in 2009 from 16 villages from the same county but without an FFS-trained farmer in their village.

The intervention villages known to grow crops with a significant use of pesticides and with accessible roads most of the year were selected after consultations with the Farmers' Union and local authorities. The control villages were the villages of farmers having attended a course given *by the Plagbol project to the Farmers Union in La Paz County and having volunteered to establish contacts within their villages and assist with the practical data gathering.*

The Intervention

The intervention between 2002 and 2004 consisted in FFS training of farmers in IPM. The FFS farmers were trained during 14 theoretical and practical courses of one to two days' duration. Educational booklets for the seven theoretical modules were developed on: 1. Pedagogic, 2. The World of Pesticides, 3. The Use of Pesticides, 4. Agricultural Pests, 5. Health Effects of Pesticides, 6. IPM Methods and 7. IPM in Tomatoes. A draft version of the booklet was used in each training course and then modified according to the input from the farmers before a final version was distributed (52).

During the trainings, the FFS farmers were trained to pass on their acquired knowledge to neighboring farmers. The transfer of knowledge was facilitated through the training in pedagogical methods, hands-on training situations and by elaboration of personal teaching materials such as flipcharts, herbarium and insect collections. A minimum of two informative trainings on 'Integrated Pest Management' and 'Adequate use of Pesticides' were undertaken by the FFS farmers in their villages. In the first village training, a supervisor from the Plagbol project watched the process in order to give feed back to the trained farmer on his performance. All FFS trained farmers have confirmed to have implemented two or more training session in their villages. According to the FFS farmers and the Plagbol supervisors, the neighboring farmers have to a large extent taken part in these informative village meetings and trainings led by their FFS farmer. Attendance were facilitated by a strict control where farmers are fined if they do not attend village meetings arranged by the Farmers Union. Informal knowledge sharing from FFS farmer to neighboring farmer also took place on a day to day basis in the villages according to information from both the FFS and the neighboring farmers, but the extent of this is not known as no record was kept. In these small and disperse villages where few things happens any news are always widely discussed and shared with neighbors, facilitating the diffusion of new knowledge.

In order to spread the IPM information, radio and television programs, newspaper articles and informative materials about pesticides were produced and distributed from 2004 to 2009 throughout Bolivia. This has been done in a scale of approximately 30 radio and 15 television programs and 100 newspaper articles. Similar information may have been relayed by other NGOs, pesticide companies or Ministry of Agriculture. The trainings given by the pesticide companies *mostly consist of short sessions typically lasting a few hours or half a day with promotion of the company's products.*

Study population

Farmers from the intervention area were invited to village meetings, briefed about the project and invited to volunteer in the baseline study in 2002. Thirty-nine male farmers, later trained on IPM methods, participated in the baseline study together with seventy-seven neighboring male farmers, from the same villages. Twenty-three of the trained farmers and forty-seven of the neighboring farmers participated in the 2009 follow-up study. The smaller number of participants in the follow-up was caused by change to ecological farming, change of job, migration or death. No significant differences in age, education and IPM knowledge and practice were seen in the baseline data when comparing farmers included in the follow-up with the missing farmers.

Farmers in the control group were recruited by chance by interviewers inviting them to participate when found at home. The control group included 138 pesticide using male farmers.

As a former survey showed significant gender difference on performance, educational level and self-reported pesticide poisonings, female farmers were excluded from the actual study due to a skewed proportion of female farmers in the three farmers groups (53). Ecological farmers were excluded as questions connected to pesticide use were irrelevant to this group.

Design

This study includes follow-up data on trained and neighboring farmers and cross-sectional data on the control farmers. As the most obvious difference between the control farmers and the neighboring farmers were having an FFS farmer in their village or not we assume that differences in knowledge, attitude and practice on IPM and pesticides (=KAP performance) between these two groups can be explained by a diffusion of knowledge from the FFS farmers to their neighboring farmers.

The study was based on a pre-tested and validated questionnaire used for the baseline study in 2002. The KAP variables included questions in the three categories 'Toxicity: use and knowledge', 'Use of personal protection and hygiene' and 'Technical handling of pesticides'; all variables tested can be seen in table 2.

Most of the variables were dichotomous. A question on 'commercial names of pesticides used' was open-ended and later recoded into variables on WHO toxicity class and chemical class of the pesticide. A variable on living altitude was created from knowledge about the village's altitude that can vary considerably in the mountains.

Trained project personnel who had piloted the interviews before starting the collection of data, conducted the data gathering. The interviews lasted about half an hour. The data were entered into Excel by a local statistician and transferred to SPSS for further analysis.

Data analysis

The dichotomous variables were analyzed using the χ^2-test test (Pearson chi-square and 'linear by linear association'). Prevalence ratios with 95% CI were calculated to compare the neighboring and the control farmers. Ordinal variables were analyzed using the ANOVA test. To summarize the results an aggregated variable was created by summarizing all the KAP variables into one KAP score with a maximum score of twenty. The soundness of aggregating variables of different kinds is discussed; but in this analysis we think the aggregated variable provides a better picture of a real life situation resulting in a more robust analysis than analyzing only the individual KAP variables. In the analysis missing values were kept missing, this resulted in fewer participants in some of the analysis, especially in the aggregated variable, but the results did not differ to any significant extent whether or not keeping the variables as missing or replacing them with for example a negative score.

To control for possible confounding by age, education level and living altitude, a stratification of the aggregated variable was implemented.

Ethical considerations

The study was approved by the Medical Ethical Committee in Bolivia. All participants were volunteers and signed an informed consent form before being interviewed. .

RESULTS

Significant differences were found when comparing the three farmers' groups as regards age and living altitude, whereas no difference was seen as regards education level, see Table 1.

Table 1: General data (FFS farmers N=23, neighboring farmers N=47, control farmers N=138)

Variables	*Farmer groups*	*ANOVA*		
		Years		*p-value*
Age, mean (SD)	*FFS farmers*	*41.3 (SD=9.9)*		*0.02*
	Neighboring farmers	*49.6 (SD=13.5)*		
	Control farmers	*45.6 (SD=10.7)*		
		χ^2- test		
		N	***%***	***p-value***
Educational level above primary school	*FFS farmers*	*17*	*73.9*	*0.23*
	Neighboring farmers	*25*	*53.2*	
	Control farmers	*78*	*56.5*	
Living >2500 meters above sea level	*FFS farmers*	*15*	*65.2*	*0.02*
	Neighboring farmers	*32*	*68.1*	
	Control farmers	*116*	*84.1*	

In 2002 19.1 % of the neighboring farmers and 26.1 % of the FFS farmers stated to have received some kind of training or information on pesticide handling. In 2009, all the FFS farmers was trained and confirmed to have given short courses, information and hands-on trainings in their villages to their neighboring farmer. This was confirmed by the Plagbol project personnel having attended at least one of the courses given in the villages by the FFS farmers to be able to give feed-back on pedagogic performance, course quality and content to the FFS farmer. In the control group, 39.1% stated that they had received some kind of training or information on pesticide handling from pesticide companies or others.

A rather high percentage of the FFS farmers and their neighboring farmers interviewed in 2002 who reported to have used WHO class I pesticides, had limited knowledge on pesticide toxicity and little use of personal protection and hygiene when handling pesticides, see table 2. A substantial improvement was seen from 2002 to 2009 in both groups.

Table 2: Knowledge, Attitude and Practice on IPM and pesticides among FFS farmers (N=23), neighboring farmers (N=47) and control farmers (N=138), (χ^2- test)

	2002		***2009***				
Variables	***N****	***%***	***N****	***%***	***Prevalence Ratio***	***95% CI***	***Analysis for trend p-value***
Toxicity - Use and knowledge							
No use of WHO Class I pesticides							
FFS farmers	*3/23*	*13.0*	*17/23*	*73.9*	*2.04*	*1.45-2.83*	*0.00*
Neighboring	*8/47*	*17.0*	*24/47*	*51.1*	*1.41*	*0.99-2.01*	
Controls			*50/138*	*36.2*			
No use of organophosphates							
FFS farmers	*0/23*	*0.0*	*15/23*	*65.2*	*2.01*	*1.39-3.01*	*0.00*
Neighboring	*3/47*	*6.4*	*18/47*	*38.3*	*1.20*	*0.78-1.86*	
Controls			*44/138*	*31.9*			
Reads instructions on container							
FFS farmers	*7/23*	*30.4*	*22/23*	*95.7*	*2.00*	*1.65-2.43*	*0.00*
Neighboring	*13/46*	*28.3*	*40/46*	*87.0*	*1.82*	*1.48-2.24*	
Controls			*66/138*	*47.8*			
Know meaning of red color label on pesticide container							
FFS farmers	*9/23*	*39.1*	*20/23*	*87.0*	*1.91*	*1.50-2.42*	*0.00*
Neighboring	*13/46*	*28.3*	*31/41*	*75.6*	*1.66*	*1.29-2.13*	
Controls			*63/138*	*45.7*			
Know meaning of green color label on							
pesticide container	*8/23*	*34.8*	*22/23*	*95.7*	*2.49*	*1.98-3.13*	*0.00*
FFS farmers	*8/46*	*17.4*	*23/43*	*53.5*	*1.39*	*0.98-1.98*	
Neighboring			*53/138*	*38.4*			
Controls							
Use of personal protection and hygiene							
Use long sleeved shirt							
FFS farmers	*10/23*	*43.5*	*19/22*	*86.4*	*2.29*	*1.75-3.01*	*0.00*
Neighboring	*10/47*	*21.3*	*23/47*	*48.9*	*1.30*	*0.90-1.87*	
Controls			*52/138*	*37.7*			
Use long trousers							
FFS farmers	*12/23*	*52.2*	*19/22*	*86.4*	*1.89*	*1.48-2.42*	*0.00*
Neighboring	*11/47*	*23.4*	*23/47*	*48.9*	*1.07*	*0.76-1.51*	
Controls			*63/138*	*45.7*			
Use hat							
FFS farmers	*6/23*	*26.1*	*18/22*	*81.8*	*1.45*	*1.13-1.85*	*0.17*
Neighboring	*7/47*	*14.9*	*23/47*	*48.9*	*0.87*	*0.63-1.20*	
Controls			*78/138*	*56.5*			
Use gloves							
FFS farmers	*6/23*	*26.1*	*15/22*	*68.2*	*1.65*	*1.17-2.34*	*0.24*
Neighboring	*5/47*	*10.6*	*13/47*	*27.7*	*0.67*	*0.41-1.11*	
Controls			*57/138*	*41.3*			
Use mask							
FFS farmers	*7/23*	*30.4*	*18/22*	*81.8*	*2.30*	*1.71-3.11*	*0.00*

Neighboring	*5/47*	*10.6*	*13/47*	*27.7*	*0.78*	*0.47-1.30*	
Controls			*49/138*	*35.5*			
Use boots							
FFS farmers	*6/23*	*26.1*	*18/22*	*81.8*	*3.32*	*2.34-4.72*	*0.00*
Neighboring	*3/47*	*6.4*	*17/47*	*36.2*	*1.47*	*0.91-2.37*	
Controls			*34/138*	*24.6*			
Wash body after spraying'							
FFS farmers	*13/23*	*56.5*	*2/21*	*95.2*	*2.86*	*2.22-3.69*	*0.00*
Neighboring	*21/47*	*44.7*	*37/45*	*82.2*	*2.47*	*1.88-3.24*	
Controls			*46/138*	*33.3*			
Change clothes after spraying							
FFS farmers	*13/23*	*56.5*	*22/22*	*100*	*1.53*	*1.36-1.73*	*0.00*
Neighboring	*17/46*	*37.0*	*35/46*	*76.1*	*1.17*	*0.95-1.43*	
Controls			*90/138*	*65.2*			
Refrain from eating, chewing coca, smoking while spraying							
FFS farmers	*18/23*	*78.3*	*21/22*	*95.5*	*1.45*	*1.25-1.68*	*0.00*
Neighboring	*42/46*	*91.3*	*41/47*	*87.2*	*1.32*	*1.13-1.56*	
Controls			*91/138*	*65.9*			
Refrain from blowing spray head when obstructed							
FFS farmers	*12/23*	*52.2*	*21/22*	*95.5*	*2.03*	*1.66-2.47*	*0.00*
Neighboring	*18/47*	*42.9*	*35/47*	*74.5*	*1.58*	*1.24-2.02*	
Controls			*65/138*	*47.1*			
Technical handling							
Check knapsack sprayer before spraying							
FFS farmers	*16 /23*	*69.6*	*22/22*	*100*	*1.24*	*1.15-1.35*	*0.02*
Neighboring	*39/45*	*86.7*	*39/45*	*86.7*	*1.08*	*0.94-1.24*	
Controls			*111/138*	*80.4*			
Refrain from spraying same day as harvest							
FFS farmers	*15/23*	*65.2*	*22/22*	*100*	*1.15*	*1.08-1.23*	*0.00*
Neighboring	*36/46*	*78.3*	*47/47*	*100*	*1.15*	*1.08-1.23*	
Controls			*120/138*	*87.0*			
Burn or bury empty pesticide containers							
FFS farmers	*6/22*	*27.3*	*16/21*	*76.2*	*1.67*	*1.24-2.25*	*0.03*
Neighboring	*12/46*	*26.1*	*20/43*	*46.5*	*1.02*	*0.71-1.47*	
Controls			*63/138*	*45.7*			
Store pesticides outside house							
FFS farmers	*17/23*	*73.9*	*20/22*	*90.9*	*1.82*	*1.47-2.25*	*0.00*
Neighboring	*40/46*	*87.0*	*44/47*	*93.6*	*1.87*	*1.56-2.25*	
Controls			*69/138*	*50.0*			
Store pesticides locked up							
FFS farmers	*4/23*	*17.4*	*5/22*	*22.7*	*6.18*	*1.95-19.62*	*0.00*
Neighboring	*2/46*	*4.3*	*4/47*	*8.5*	*2.30*	*0.65-8.26*	
Controls			*5/138*	*3.7*			

*Note: *Number of included farmers with valid answers is given in all variables.*

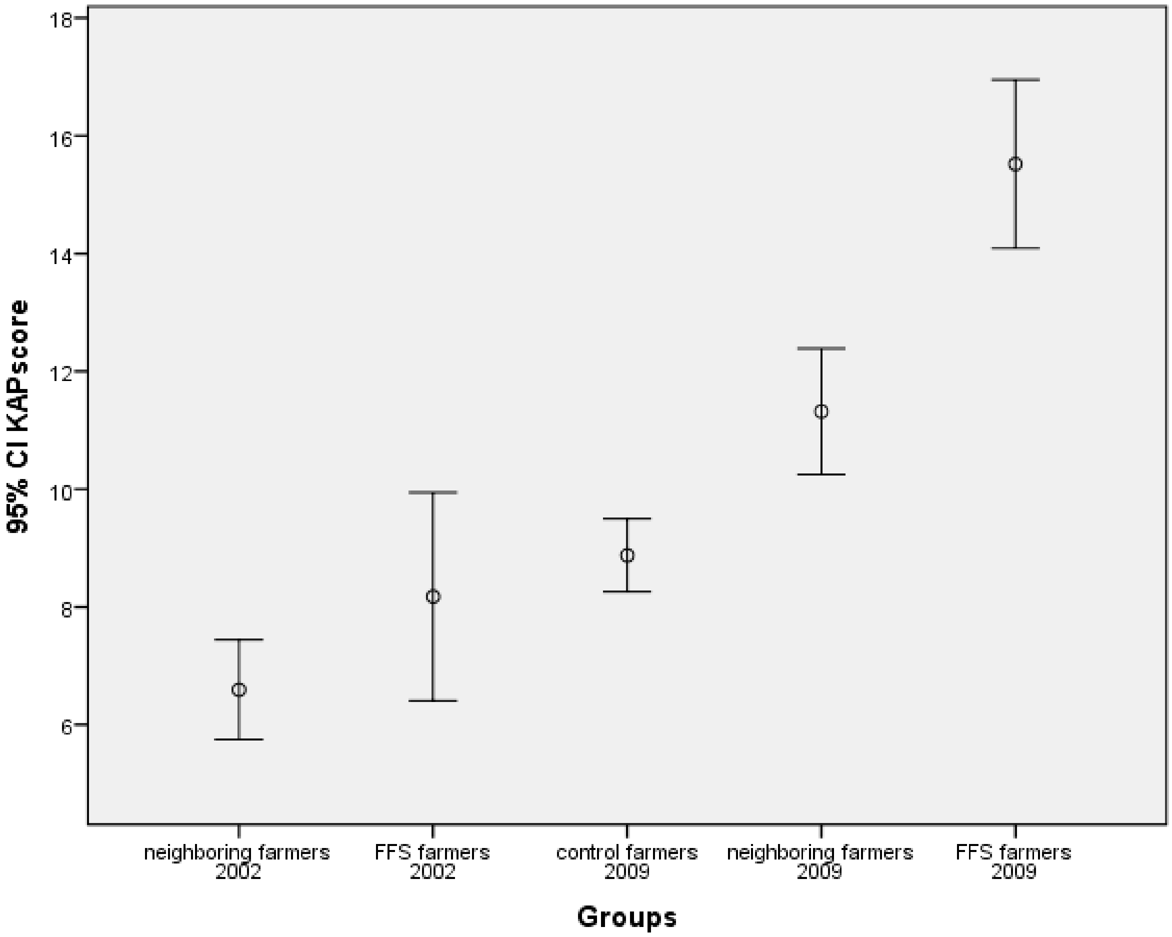
When comparing the performance of the three farmer groups in 2009, a positive trend of increasing performance was seen, with the control group farmers performing worst and the FFS farmers best in all variables except for 'use hat', 'use mask' and 'use gloves', see Table 2. If we look at the prevalence ratios (PR), we see that the FFS-trained farmers have significantly higher PRs in all variables compared to the control farmers, varying from 1.15 to 6.18. The neighboring farmers had higher PR than the control farmers in most of the variables, of which seven were significant, $p<0.05$, and two borderline significant, $p<0.10$, see Table 2.

In 2009, an increasing trend was seen, with the control farmers scoring lowest and the FFS-trained farmers scoring highest in the aggregated KAP score, see fig 1. Comparisons between each of the groups using the Tukey HSD test showed significant difference in performance among all three groups $p<0.01$.

When stratifying the groups into age above or below 45 years of age and on altitude of residence, the same picture was seen with significant increasing means from the controls to the FFS trained farmers. In the Tukey HSD test, the difference between controls and neighbors became borderline significant for age groups above 45, and non-significant for living above an altitude of 2500 meters, while the difference between neighboring and FFS trained farmers became non-significant for living below 2500 meters. (Data not presented).

The performance of both the FFS farmers and the neighboring farmers improved significantly from 2002 to 2009 with an increasing mean of the aggregated KAP score in both groups. The mean became significantly better for the FFS farmers than for the neighboring farmers from 2002 to 2009, se fig 1.

Fig 1: Aggregated score on Knowledge, Attitude and Practice on IPM and pesticides in farmers groups (Means with 95% confidence intervals)



Note:

Neigboring farmers 2002 (N=47) mean 6.66 95% CI 5.81-7.51

FFS farmers 2002 (N=23) mean 8.17 95% CI 6.41-9.94

Control farmers 2009 (N=136) mean 9.18 95% CI 8.55-9.80

Neigboring farmers 2009 (N=34) mean 11.97 95% CI 10.56-13.38

FFS farmers 2009 (N=20) mean 16.55 95% CI 15.45-17.65

Degrees of freedom were 4 between groups and 255 within groups

Mean squares were 408.59 between groups and 12.67 within groups, with an F-value = 32.13 and a p-value = 0.00

DISCUSSION

The cross-sectional study from 2009 showed significant differences between the FFS farmers, the neighboring farmers and the control farmers on both the individual KAP variables and an aggregated KAP score evaluating the knowledge and use of pesticides. The follow up study from 2002 to 2009 showed a significant improvement on the aggregated KAP score both among the FFS-trained farmers and their neighboring farmers.

The intensive training of the FFS farmers explains their significant better performance in all variables compared to the neighboring farmers and the control farmers. A dissemination of knowledge from the FFS farmers to their neighboring farmers might explain why the neighboring farmers perform better than the control farmers, as the most obvious difference between the neighboring farmers and the control group farmers regarding opportunities to improve their performance on pesticide handling and IPM was the existence of an FFS-trained farmer in their village.

The difference in the mean of the aggregated KAP scores of the FFS and neighboring farmers in 2002 to the mean of the control group farmers in 2009 could represent a 'period effect' probably seen among all Bolivian small holder farmers, assuming that the score among the control group farmers would have been at the same level as the two other farmer groups if measured in 2002. A 'period effect' can be explained by a generally increased use of pesticides among small-holder farmers in Bolivia who have got information from reading pesticide container labels, pesticide companies and salesmen. If this assumption is correct, then we can calculate a period effect of 2.0 score points from 2002 to 2009 which means that 38% of the improvement seen among the neighboring farmers and 23% among the FFS-trained farmers might correspond to a period effect. Due to the mentioned assumptions, this must be interpreted with much caution, however.

A 'dissemination of knowledge' from FFS farmers to neighboring farmers is part of the FFS strategy as this might help justify the costs of the training of farmers (21,22,50). Some studies reported a probable dissemination of knowledge (22,28,31,32,49), while the majority did not find any significant dissemination from trained to untrained farmers (20,44-48,50). Plausible explanations for the lack of dissemination could be the knowledge of IPM techniques being too complicated to pass on from farmer to farmer, that more time is needed for knowledge to diffuse, that participants were not sufficiently involved in the farmer network or that the quality of the intervention in terms of curriculum and facilitation was too poor (19-22,34,50,54,55). It is argued that traditional agricultural extension service that focuses on disseminating simple knowledge and *practices like adoption of improved seeds and application of pesticides and fertilizers is much easier to understand and bring into use thus being easier to diffuse as well (20,41,56).*

A fair assumption is that farmers are more likely to share information the more knowledge and experience they have, as shown in a study where FFS-trained farmers and farmers trained in workshops more readily shared their knowledge compared to farmers having only received superficial knowledge from the radio (41). We draw attention to the fact that our positive results on dissemination could be due to our focus in the trainings on pedagogics and 'sharing knowledge' as described in 'Methods', an approach we have not seen described by others.

Our findings reported in a former publication showed that the neighboring farmers continue to improve their knowledge years after the training of FFS farmers stopped, while the FFS farmers improved until their training stopped and then they maintained their acquired knowledge (30). The reason for the later but ongoing improvement among the neighboring farmers compared to the FFS farmers could be that the FFS farmers keep sharing knowledge years after their own training has stopped. Therefore, premature evaluation of the eventual improvement among neighboring farmers may not allow the necessary time for a significant diffusion to happen and thus not show a positive result.

The training of farmers and the extension services offered by most governments in low-income countries is scarce because of the high costs. We calculated the costs amounting to approximately $150 US per FFS-trained farmer (pers.com. O Huici Plagbol project, July 2014), others have reported costs from 12 to 84 $ per trained farmer during a growth season (22,46,49,29). These differences are explained by the length of the courses, the costs of the information materials provided, costs of accommodation and food and the different cost level in different countries. Many studies found higher yields and lower pesticide expenses as a result of the trainings on IPM (19-22,24,28,31,32,44,49). A couple of studies have made cost benefit analyses showing the costs of training to be justified as they are compensated by the higher yields and lower pesticide expenses (31,29).

Limitations and strengths

Our study has several limitations due to mixing the 'research interests' with the 'interests of a development project' as discussed by other researchers (51).

One of the problems was the selection of participants. FFS farmers were selected on purpose by the villagers when asked by the project to select a fellow farmer of confidence who could read and write to go for the IPM trainings. Neighboring farmers and controls were selected by chance if *found at home when visited by the interviewers. This leads to a selection bias and we have to be cautious not to generalize results especially on the highly selected group of FFS farmers. Comparable intervention projects having selected farmers for training, often report the trained farmers to be younger and better educated than their fellow farmers, as also seen in our survey (45,47,48,50). Random selection is inconvenient to practice in most low income countries because of the lack of reliable population registers, many people living in the countryside without a formal address.*

Information bias may occur as all data were self-reported and the interviewed might just have given the answers by chance or the answers the interviewer supposedly wanted to hear.

The sample size was a limitation, especially when trying to stratify in a controlled analysis as the numbers in each group of farmers often became too small to reach significance although marked differences were seen in the figures.

Finally the influence of information activities on pesticides from other institutions apart from the interventions by the Plagbol project are difficult to control but as all farmers were likely to have been exposed to the same 'external influence' this bias might be of less importance.

CONCLUSION

This study showed that farmers trained on IPM did improve their performance considerably from the first evaluation in 2002 to the last one in 2009. This was also true - although to a lesser extent - for their neighboring farmers, a fact that may be explained by a diffusion of knowledge from the trained farmers, seeing that the neighboring farmers performed better when compared to a control group of farmers in 2009. The dissemination of knowledge was facilitated by the focus on pedagogic methods in the training of FFS farmers. The diffusion of knowledge can contribute to justify the costs and help to convince donors and governments in low-income countries about the benefits of farmers training on IPM.

Competing interests

The authors declare that we have no competing interests.

Authors' contributions

EJ was the leader of the research. He contributed to all phases of the research project from conception and design, the acquisition and analysis of data to the writing of the manuscript. FK contributed to the revision of the manuscript for intellectual content. OH contributed to the conception, design and the acquisition of data. RCM contributed to the conception and design and the acquisition of data. JV contributed to the revision of the manuscript for intellectual content. FL contributed to the conception and design, the acquisition of data and the revision of the manuscript for intellectual content. All authors have read and given their final approval for this version to be published.

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Paper 4

Title: Obstacles and possibilities for diffusion of Integrated Pest Management strategies among Bolivian farmers to control negative consequences of inadequate pesticide use!

Jørs Erik, Aramayo Antonio, Huici Omar, Konradsen Flemming, Gulis Gabriel

Abstract

Introduction: *Integrated Pest Management (IPM) offers different solutions to control pest resistance, human poisoning and pollution caused by incautious and indiscriminate pesticide use in agriculture. This article discusses the opinions of Bolivian farmers and agronomists on obstacles and opportunities for diffusion of IPM.*

Methods: *Focus Group discussions (FGDs) were conducted with three groups of farmers and two groups of agronomists all with practical working experience from IPM farming. Roger's theory on Diffusion of Innovations was adapted to relevant IPM themes in the FGDs with a focus on the 'innovation' of IPM compared to traditional agriculture and the 'possibilities to make alliances' for spreading IPM to other farmers.*

Results: *The FDGs agreed on the most important obstacles being the increased workload without certainty of higher yields or prices with IPM compared to traditional agriculture. In favor of IPM was lower production costs (when not counting the value of labor force); the increasing awareness on the importance of a healthy and sustainable food production; the easiness to try out IPM and modify the methods according to needs and the IPM being in line with traditional cultural beliefs about protection of the environment.*

Conclusion: *For IPM to spread, farmers must accept an extra workload not always compensated by increasing yields and/or prices of the products. To overcome these barriers, a healthy and sustainable agricultural production must be a priority. National governments must take responsibility and secure relevant support to farmers through agricultural extensionists giving training to farmers, loans to IPM productions and better prices for the healthier farm products, instead of supporting the use of pesticides. This can be done by following the UN guidelines in the International Code of Conduct on Pesticides.*

Introduction

Improper use of pesticides in farming can result in the development of pest resistance and have negative impacts on human health and the ecosystem . To confront the negative effects hundreds of thousands of farmers have been trained in Integrated Pest Management (IPM) on Farmers Field Schools (FFS) by FAO, IFAD and others (5-9). The training has most often been on specific crops and typically taking place during a growth season using interactive and locally adapted learning processes (5-9).

Recent reviews found significant positive effects of FFS training such as improved knowledge and adoption of good agricultural practices, increased use of ecological methods for pest control, reduction in the amount of pesticides used and increase in the yields and profits (10,11). The reviews showed mixed results on health outcomes and found no significant spread of knowledge from trained farmers to neighboring farmers (10,11).

In spite of these results IPM farming has not been diffused to any significant extent whereas farming with increased pesticide use especially in low-income countries is seen from FAOSTAT comparing import value of pesticides over the last decades (12). Drivers for increased pesticide use are many e.g. growing crops highly susceptible to pest attacks, monoculture on big fields, high pest incidences due to climate, development of pest resistance, aggressive marketing by pesticide companies, a growing informal market for discounted pesticides, lack of extension services, lack of knowledge of alternative methods for pest control, political priorities like subsidies for pesticide use and loans for agricultural inputs tied to purchase and use of pesticides (13-16).

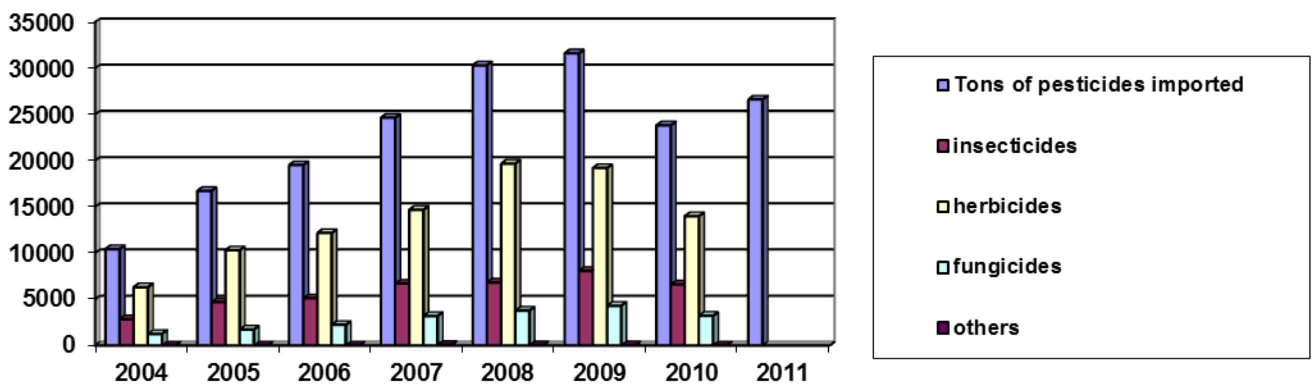
It is discussed whether IPM is a realistic alternative to conventional pesticide consuming agriculture in low-income countries and the provoking question "Integrated Pest Management for Resource-Poor African Farmers: Is the Emperor Naked?" has been posed (17-19). Reasons for the low diffusion rates of IPM might be too complex IPM curriculum, low literacy among farmers, wrong strategies for approaching participants, lack of local leadership, no supporting policy for IPM diffusion and limited human resources to teach and facilitate the diffusion (9,11,17,20,21). It is argued that IPM knowledge is too complicated to diffuse compared to traditional agriculture that tend to focus on simple knowledge and practices like adoption of improved seeds and application of pesticides and fertilizers (11,22,23).

A recent study compiling viewpoints on obstacles to IPM diffusion in low-income countries found 51 unique viewpoints (21). The obstacles most often mentioned were "insufficient training and technical support to farmers", "lack of favorable government policies and support", "farmers' low level of education and literacy", "IPM too difficult to implement", "powerful influence of pesticide industry", "benefits of pesticides are much more apparent than their negative effects", "shortage of funding for IPM" and "IPM requires collective action within farming communities".

The Bolivian context

Pesticides were introduced in Bolivia in the 1960s among big scale farmers in the tropical areas with the implementation of the political plan "Colonization of the East" and were later taken up by small-scale farmers (24,25). During the period 1990-2012 the import of agrochemical products multiplied in value from US$ 6.4 million to US$ 185.1 million according to FAOSTAT.

The classes and amounts of pesticides imported are seen from Figure 1 (reported by SENASAG on the conference 2do. Congreso Internacional "Plaguicidas y Alternativas" Santa Cruz, Bolivia 2012).



In Bolivia the same picture as in other low-income countries with the use of very toxic pesticides, no or little use of personal protective equipment and insufficient hygiene leading to frequent acute intoxications among farmers has been shown (26). IPM in agriculture was introduced in the late 1990s through the International Potato Center (CIP) and its partners focusing on research on potatoes and quinoa, with training and extension services in some areas of Bolivia (22,27,28). From 2001 to 2013 the Bolivian NGO Fundacion Plagbol *promoted IPM by training among small-holder farmers and also achieved a change in curriculums to mainstream IPM training in Bolivia's Technical Agricultural Schools and at the Faculties of Agronomy (25). The project also facilitated a change in the policy of the Ministry of Agriculture from relying only on pesticides and having farmers training by the pesticide industry to the actual focus on IPM training of small-holder farmers by the Ministry's operative branch SENASAG (25).*

The objective of the present survey was to explore the possibilities for IPM diffusion, and as a guide for the Focus Group discussions, Roger's theory on 'Diffusion of Innovations' was adapted (29). This theory offers tools to describe how, why, and at what rate new ideas and technologies spread, including four elements of importance for diffusion: the innovation itself, the communication channels, a time factor, and the social system. For this study, the theory was adapted to focus on the innovation and the possibilities to make alliances for spreading the innovation.

Methods

Design

This study is based on the information gathered from three Focus Group discussions (FGDs) with farmers and two with agronomists from La Paz County. The Plagbol personnel invited participants with IPM experience from trainings and practice. Eleven farmers from the Municipalities Caranavi and Comarapa were included, with one group consisting of coca and coffee farmers, a second group of vegetable farmers and a third a group of strawberry farmers. Two agronomists from the Faculty of Agronomy in La Paz and three from the Technical School of Agriculture in Caranavi took part in a FGD each.

The FGDs were conducted by two agronomists – of whom one not being a staff of the project acted as facilitator in the discussions and the other recorded the discussions, observed and helped with practicalities. The FGDs took place in September and November 2013. The discussions were held in Spanish, tape recorded and shortly thereafter transcribed and systematized.

As we found that farmers do not readily distinguish between IPM and ecological farming, this survey included farmers implementing only some IPM techniques to pure ecological farmers. Our experience is that many farmers trained in IPM switch to ecological farming in all or part of their production according to the market possibilities or their personal interest (30).

The FGDs included but were not restricted to the following themes: 1. Comparative advantage - evaluated by comparing IPM and traditional agriculture on the need of investments, labor demand, size and value of the yield. 2. Compatibility - evaluated by how easy IPM fits into 'preservation of Mother Earth' (local synonym for the environment), agricultural practices in use, and norms and regulations given by the state for agricultural production. 3. Complexity - evaluated by the ease of understanding the innovation, and the complexity of the new method. 4. Triability- evaluated by the cost of trying out IPM, the ease of using the practices, and the ease of detecting short-term results. 5. Observability – evaluated by the perceived size of the yields and the quality of the products, 6. Re-invention – evaluated by the ease to improve IPM methods by adapting new ideas and experiments and trials, and 7. The creation of alliances – evaluated based on the ease to build relations and sharing the IPM experiences with others

Each Focus Group (FG) was told to come up with one joint score on each of the themes discussed, either 1. As advantageous in itself or compared to traditional practices (recorded as 'higher', 'high' or 'easy'), 2. Equal to traditional practices (recorded as 'equal'), 3. Less advantageous in itself or compared to traditional practices (recorded as 'medium') or 4. Definitely less advantageous in itself or compared to traditional practices (recorded as 'difficult' or 'low'). In total 80 scorings were recorded. To support the ratings the groups were asked to provide arguments to support their score and 156 unique statements came up.

All participants signed an informed consent form before participating and had the right to withdraw during the FGDs. The project held a right to collect such information as part of the project activities within the project period.

Results

Farmer and agronomist ratings of IPM are shown in Table 1. All arguments made in support of the ratings are available in the Annex from where some arguments are cited below.

Comparative advantage of IPM in relation to traditional farming

The overall evaluation showed no difference in comparative advantage between IPM and traditional agriculture when including all FGDs ratings. If restricted to only farmer FGs, IPM was rated to have fewer advantages than conventional agriculture (table 1).

Table 1 Focus Groups' ratings of IPM

Components evaluated		***Coffee/coca Farmers (N=3)***	***Vegetable Farmers (N=3)***	***Strawberry Farmers (N=5)***	***Agronomist UMSA (N=2)***	***Agronomist ISTAIC (N=3)***
Comparative advantage	*How is the production costs of IPM compared to conventional agriculture?*	*Lower*	*Higher*	*Lower*	*Lower*	*Lower*
	How is the labor force needed in IPM compared to conventional agriculture?	*Higher*	*Higher*	*Higher*	*Higher*	*Higher*
	How are the yields of IPM compared to conventional agriculture?	*Equal*	*Lower*	*Lower*	*Equal*	*Higher*
	How is the value of the IPM crops compared to conventional agriculture?	*Higher*	*Equal*	*Higher*	*Higher*	*Equal*
Compatibility	*How is the compatibility of IPM with local culture?*	*High*	*High*	*High*	*High*	*High*
	How is the compatibility of IPM with the national production regulations (CENAPE, organic production)?	*High*	*High*	*Low*	*High*	*Low*
	How is the compatibility of IPM with known agricultural practices?	*High*	*Medium*	*Medium*	*Medium*	*High*
Simplicity	*How easy is it to understanding IPM practices?*	*Medium*	*Medium*	*Medium*	*Easy*	*Easy*

	How easy is it to use IPM?	*Medium*	*Medium*	*Medium*	*Medium*	*Medium*
Triability	*How high/low are the costs of trying out IPM?*	*Low*	*Medium*	*Low*	*Low*	*Low*
	How easy is it to try out IPM techniques?	*Easy*	*Easy*	*Easy*	*Easy*	*Medium*
	How visible are the results when trying IPM?	*Easy*	*Medium*	*Medium*	*Easy*	*Medium*
Observability	*How easy is it to observe an increase in the yield of IPM?*	*Difficult*	*Difficult*	*Difficult*	*Medium*	*Medium*
	How easy is it to observe improvements in the quality of the IPM products?	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*
Re-invention	*How easy is it to incorporate new ideas for improving and adapting IPM based on own experience?*	*Easy*	*Easy*	*Easy*	*Easy*	*Easy*
Alliances	*How easy is it to find allies to disseminate IPM?*	*Medium*	*Difficult*	*Difficult*	*Medium*	*Difficult*

Green - in favor of IPM, white - neutral, yellow - some disfavor, red - absolute disfavor

There was full agreement among the five groups on IPM being more work intensive compared to conventional agriculture. The reasons are summarized in the following statement "as local inputs are used, they should be collected, prepared and applied; in the case of chemicals, they only should be bought and applied".

Regarding the size of the yield Farmer FGs rated the yield lower to equal whereas the agronomist focus groups rated the yields equal to higher. The arguments forwarded by the farmers were "at the beginning, it is hard to produce and the yield is lower, but it becomes equal in time.", and "the size of the fruit is smaller than the conventional one." The agronomists found that "the good fertility of the soil is a consequence of the IPM, which is why the harvests are more regular related to yields and more sustainable."

The value of the harvest was rated higher to equal depending on the type of crop grown by the farmers, where ecological coffee and strawberry apparently have better markets than vegetables. Coffee and coca farmers argued that "consumers pay for the quality of organic coffee and coca, they even look for them at the small farms." A problem is the certification of the products grown ecologically or using IPM, as stated by the group of agronomists "there is no certification that guarantees the quality of the product, which is why the consumers do not feel confident to pay more."

Interestingly the influence of the products on the health and the environment also matters as stated by both farmers and agronomists: "The yield is important, but it is more important that the product is healthy, so we do not get poisoned when producing and consuming it."

Compatibility, with existing values, regulations and practices

There was agreement on rating the compatibility of IPM as high: "Because it gives recognition to the ancient practices of respect to the Pachamama (Mother Earth)", and "in the past we took care of the soil, the water and the environment, but then we started producing only with chemical products. We realized that it was not good, that everything was receiving damage. Now we look for saving the environment, not damaging it" as expressed by the farmer groups. Regarding compatibility with national regulations the ratings varied. Those rating it low found that although regulations were in place, missing implementation and control make the regulations useless.

The compatibility of IPM with the practices that farmers commonly carry out was rated as equal to high. Farmer groups still found it demanding to practice IPM stating, "the grounds are the same but IPM requires more knowledge on the root of the problems and how these *can be overcome. Study, experimentation and tests are required to be sure of its usefulness."* and *"almost everything of conventional agriculture is useful, but IPM improves the agriculture a lot, although it is not so easy to put into practice, it is necessary to learn a lot of things and make decision to do things well."*

Simplicity, to understand and use

The agronomist groups rated the simplicity of understanding IPM as high and found IPM techniques easy but were aware of the necessity to create awareness on the benefits of IPM with regard to health and the environment and to use appropriate educational material accompanied by practices. Farmers groups found IPM more complex to understand: "It is not easy to identify pests, diagnose, know-how to control them and dose pesticides. Because of our low educational level it is hard for us to memorize, we do not read much - that is why practice helps."

There was agreement of categorizing the IPM practice as medium complex. The arguments for this from the farmer groups were "The IPM activities take time, new complementary techniques are required. One thing gives continuity to the other and isolated practices does not work." and "It is not complex but you should be dedicated, it is necessary to do things well and in due time."

Triability - easy and not too costly in time and money to try out

The ability to test the IPM methods was judged easy to medium. All but one FG found no major economic obstacles to try IPM. The FG indicating medium difficulty to test IPM argues: "The costs are low considering that all the required material is near (in the community), but it takes time and is laborious. Testing is cheap, because almost everything you need can be found in the field, but you should be strict, do things well and on time to see results."

Similarly there was consensus between all but one FG about the easiness of testing the IPM techniques in a practical way. One agronomist FG found it medium difficult to test stating: "Sometimes, making a necessary product takes 3 months that is why the producers should anticipate the situations and be prepared."

The ability of the IPM techniques to show results in a short time was rated from medium to easy. "There are quick results in some cases, but the final result is only known when the harvest is obtained and that takes time", as stated by the vegetable farmers' FG. Similarly, *"In the cases of light and color traps, the results are immediate. However, results take place based on the sum of the actions or techniques applied" as stated by the agronomists FGs.*

Observability - immediate and visible positive effects

The size of the yield observed with IPM was rated as equal to lower among the farmer FGs and equal to higher among the agronomist FGs. The farmer FGs stated: "it takes time and effort to apply the IPM and the yield is not always higher", and "the yield is lower but it can be compensated with the longer useful life of the plants." The agronomist FGs found "an interesting yield is achieved if there are good conditions, that is, if there is a good start of having soil with good characteristics".

Again, the size of the yield was argued by all both farmers and agronomist FGs not to be the only thing that matters, as a healthy production avoiding environmental damage matters as much.

Regarding the quality of the products, the FGs said that the product attributes were easy to notice, most of them could be perceived through the taste and texture of the product. Several Focus Groups pointed out that the size and visual quality were not always the best compared to traditional agriculture.

Re-invention - the possibility of incorporating new elements based on practical experience

All groups found it easy to add their own ideas and experiences and most felt that they had contributed in some way to the adaptation and improvement of the IPM techniques in their local setting. The following FG opinion supports this: "New experiences are made available for technicians and farmers, they test them and in this way they are disseminated. We are always trying new things. The good results are shared with the promoters and everyone gets to know them."

Alliances - support and relations that can be created to promote the dissemination of the innovation

It was rated as difficult to create alliances to diffuse IPM by all FGs due to lack of support from the local political systems: "It was difficult to find allies. The Mayor's office which is supposed to care more about these subjects, has not done much in the last two years, and now it is worse because it is not working for two months already.", and "the Mayor's Office only contributes to the training of other farmers. It does not provide enough support to the strengthening of the association of organic producers." Experience with relations to other

Authorities were mixed, sometimes good and sometimes they did not materialize in spite of good spirit. The agronomist FGs stated: "There were difficulties at the university itself to find allies among the authorities and the professors. It is easier outside the university, among the professionals carrying out rural extension activities. There is favorable institutional context and generalized awareness for the dissemination of IPM".

Discussion

In summary, there was full agreement among the five groups on IPM as being more labor intensive, not always compensated by higher yields or prices of the production and requiring extra knowledge to practice compared to conventional agriculture, all issues talking against diffusion of IPM.

On the other hand, IPM was found more in line with traditional culture with respect to the nature, IPM was cheap to try out and the products were found to have a high quality regarding smell and taste. The question though is with what weight the various aspects contribute to the decision of a farmer to adopt IPM strategies or not?

An apparent important obstacle for adopting IPM is the extra workload required by IPM techniques. Most farmers are probably looking for farming techniques that give them less workload so they can cultivate more land and increase their income or dedicate some of their spare time to other income generating activities. The growing industrial production in low-income countries moving people to the cities, leaving fewer hands to cultivate the land and still feed an increasing population is not favoring the introduction of more labor-intensive agricultural practices with lower to equal yields. In Bolivia, the demand for higher food production has increased the size of cultivated land especially in the tropics where large areas of virgin land are taken under the plow these years (24). This picture might be different in countries with little arable land, and could be one of the reasons as to why there is apparently more success with IPM in Asia.

The finding of a lower to equal yield in our study is not what is seen in most other studies generally reporting a higher yield after training in farmer field schools (11). The difference might be due to the type of crops grown, as many of the positive reports stem from rice farming in Asia, seeing massive pest resistance to pesticides from the late 1980s and where IPM was found to be a very valuable tool (5,20). Other factors responsible for the increased *yield reported could also be due to climatic differences, variance in pest resistance and better conduct of FFS.*

The value of the harvest could compensate for a more labor-intensive production and a lower yield but it depends on market demands where the vicinity to the markets of the big cities and customers requiring ecological products are crucial. In our study, the type of crop seemed to be important as indicated by the coffee, coca and strawberry farmer groups who reported better prices for their ecological products. The vegetable farmers complained of a lack of awareness among consumers of the quality of their products and the lack of a certification making it difficult to charge consumers a higher price for their products.

An initiative to improve the chances of farmers making economically sound choices in their farming would be the introduction of more complete accountability as most smallholders do not calculate the value of hours spent in the field, value of agrochemical inputs purchased and income when selling the crop (19). On the Plagbol project, trials have shown variable results comparing profits by IPM farming sometimes surpassing conventional farming and sometimes not (31-33). Such calculations are not easy to make and might be difficult to generalize as they vary a lot depending on local circumstances.

The techniques of IPM were found not that easy to learn, although some are quite similar to conventional and ancient farming techniques, while others may require new skills (7-9,21). In this regard the lack of sufficient extension services for farmers in general and especially on IPM issues is a hindrance for the diffusion of IPM (11,21,24,25). Moreover, FFS need good facilitators with appropriate knowledge on IPM to obtain positive results (17,21,34,35). A problem for the extension is the general low educational level of the farmers that must be addressed by producing adequate training materials and practical learning in the fields (5,11,21).

An option for diffusing knowledge is to use IPM trained farmers to train other farmers. The farmers trained by Plagbol are found to be playing an active role in spreading IPM among their fellow farmers by taking part in certifying IPM and ecological products in the Municipalities and by conducting courses and extending IPM to other farmers and financed by the Municipalities (25). This diffusion among farmers, however, has been difficult to show in evaluations of other IPM FFS projects (11).

Allies to spread IPM are apparently difficult to find which is critical as the existence of government policies to support an innovation by taxes, prices, quotas and other regulation *factors are crucial for the diffusion of an innovation (13,17). In Bolivia, several policies and activities for mainstreaming IPM and ecological production have been initiated during the last years, but although there might be laws and regulations in favor of IPM these have to be followed up by sufficient control and support if positive results are to be seen. It is argued that more focus on communication to increase awareness and knowledge about IPM could be one of the most important tools for a massive diffusion of IPM (36).*

Awareness about health and environmental issues are of increasing importance and there IPM products are favored as they were found healthier and better for the environment as mentioned by the Focus Groups. In Bolivia, segments of the population, mainly from the big cities, are now looking for alternatives to conventional farm products, probably influenced by the international trend that has increased awareness about pesticides responsible for harm to health and the environment favoring ecological products (25). This trend can be strengthened through communication of market development of IPM products, where it is argued that consumers once convinced that IPM products are better also will be willing to pay a premium price (36).

Another hindrance for diffusion of IPM is that a clear definition of IPM is lacking, making it difficult to distinguish IPM products from conventional ones, in contrast to ecological products having a stronger brand by the right to claim 'zero pesticides'. Maybe certification and awareness raising on this issue could promote higher prices for IPM products as well.

As it is now, even the pesticide industry can claim they promote IPM although they often pay their salesmen according to the amount of pesticides sold, which is in clear contradiction to the intention of IPM strategies to reduce the amount of pesticides used (14,37).

No actual critical pest resistance might also be a hindrance for spreading IPM as farmers, agronomists and politicians in this situation cannot see any drastic decrease in productivity and therefore have no urgent need to change current practices. Radical changes in pest control practices including IPM are much more likely to come about and can happen very fast when pest resistance is seriously damaging the harvest (18,38).

In the Code of Conduct by the UN on Distribution and Use of Pesticides several important articles relate to promotion of IPM and emphasizing responsibilities of stakeholders including governments, pesticide manufacturers, farmers, researchers, consumer groups, donor agencies. In the Code, the main message is that all effort should be done to promote IPM, and activities leading to increased and unjustified use of pesticides are not acceptable.

If the Code of Conduct were taken seriously by especially Governments and Pesticide Companies, the increasing health and pollution threat from pesticides would not be such a serious issue.

Conclusion

The most important issues that might explain the lack of diffusion of IPM seem to be the extra workload and the equal to lower yields not always compensated by higher prices of the products when compared to conventional agriculture. This is not in line with the current demand for increased agricultural productivity by fewer hands on the farms. Allies for an effective diffusion of IPM seem to be lacking although many institutions have taken on IPM as part of their policy and training. The complexity of understanding and practicing IPM techniques are less pronounced hindrances but still of importance as long as sufficient extension services do not exist in most low-income countries. In favor of IPM diffusion is increased demand and thus value of certain crops, lower production costs, health and environmental advantages fitting into local culture, ease to modify and try out IPM and positive changes in quality of the product regarding smell and taste.

After more than 20 years with training on IPM in various parts of the world without being able to spread on a large scale it seems obvious that the diffusion must be politically driven to have a significant effect. This can be done by investing in adequate national extension services, introducing a certification system for IPM and ecological products, and reforming the educational system. Moreover, an effective control with imports and sale and the banning of the most toxic pesticides must be undertaken. Broad awareness raising campaigns in the public must be supported to increase consumer demand for a sustainable and healthy food production.

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Annex: Focus Groups' ratings and arguments on the IPM innovation

Components evaluated		***Farmers (N=3)*** ***(coffee - coca)*** ***Caranavi***	***Farmers (N=3)*** ***(vegetables - fruits)*** ***Caranavi***	***Farmers (N=5)*** ***(strawberry)*** ***Comarapa***	***Professors at the faculty of agronomy – UMSA (N=2)*** ***La Paz***	***Professors at the Technical Institute of Agriculture ISTAIC (N=3)*** ***Caranavi***
		Ratings and Arguments	***Ratings and Arguments***	***Ratings and Arguments***	***Ratings and Arguments***	***Ratings and Arguments***
	Production costs compared to conventional agriculture	*Lower* *Many inputs are local.* *Most of what is needed is nearby.*	*Higher* *Preparation of inputs is expensive in time.* *Cannot be obtained in the market.*	*Lower* *Own preparation of inputs.* *It is prepared with local products.*	*Lower* *Local cost-free inputs are used.* *Less quantity of product is applied in an efficient way, lowering costs.*	*Lower* *Local products are used* *The IPM reduces the environmental cost and maintains the soil preserving its characteristics and fertility.* *It watches out for the consumer's health.*
	Use of labor force compared to conventional agriculture	*Higher* *Products should be collected and this takes time.* *Care should be given to the preparation and wait some time until it is ready for use.*	*Higher* *Because of the application of several techniques that are generally manual.* *The production of bioinputs takes time (collection, preparation, maturing).*	*Higher* *Manual work is required more frequently.* *Agrochemical products that reduce the use of manpower cannot be used as weed-killers.*	*Higher* *Some activities that require more work are carried out.* *As local inputs are used, they should be collected, prepared and applied, in the case of chemicals, they only should be bought and applied.*	*Higher* *The products should be prepared, because they cannot be bought in the market.* *The products should be looked for in the field, time is allocated to the preparation until the input is ready.*
Comparative advantage	***Yields compared to conventional agriculture***	*Equal* *At the beginning, it is hard to produce and the yield is lower, but it becomes equal in time.* *The yield is higher regarding vegetables.*	*Lower* *It is difficult to produce in large quantity, there are many problems for the cultivation and the pests persist in the area.* *Cultivation in small farms, the yield is not so important. The main thing is that the product is healthy and does not harm the health like before.*	*Lower* *The size of the fruit is smaller than the conventional one.* *The useful life of the plant is longer with IPM.*	*Equal* *The quantity may be the same but the quality of the product is higher, which is why it gets better price in the market.* *The IPM is not basically aimed at increasing the yield, but at getting a cleaner production with the exact amount of pesticide, generating safe conditions in the use of pesticides for*	*Higher* *The good fertility of the soil is a consequence of the IPM, which is why the harvests are more regular regarding yields and more sustainable.* *It is important to carry out a proper and opportune management of the crop, for which purpose the well applied chemical control helps.*

					the farmers and avoiding environmental damage.	
	Value of the crop compared to conventional agriculture	*Higher* *Middlemen start to pay more for the product.* *Consumers pay for the quality of organic coffee and coca, they even look for them at the small farms.*	*Equal* *The value of the efforts made by the producer is not recognized.* *The quality is not appreciated.*	*Higher* *Consumers start to look for organic strawberry at better price, although the qualities of this product are not recognized yet in the market in general.* *The organic certification gets complicated because of the pollution originated in the neighboring areas.*	*Higher* *The quantity may be the same but the quality of the product is higher, which is why it gets better price in the market.* *Organic production is more and more demanded in the market, the prices it gets are higher than the prices of the conventional product.*	*Equal* *The market does not recognize the quality, it pays the same as per the conventional product, which is why they get mixed in the market.* *There is no certification that guarantees the quality of the product, which is why the consumers do not feel confident to pay more.*
	Compatibility with local culture compared to conventional agriculture	*Higher* *Because of the recognition it makes of ancient practices of respect to the Pachamama, which are present among the families of the communities.* *It supports the protection of the environment.* *It takes care of the people's health.*	*Higher* *In the past we used to take care of the soil and the environment, then we started to produce only with chemicals. We realized that this was not good, that it was damaging everything. Now we are looking for recovering the environment, not damaging it.* *With the cultural values, there is recovery and exchange of ancient knowledge of the communities, which is good for the new generations.*	*Higher* *The environment is not contaminated with agrochemical product residues or containers.* *It is renewed, the offerings to the Pachamama are again practiced.* *The observation of the lunar phase is practiced to sow.*	*Higher* *Direct contribution is made for the conservation of the environment and natural resources that sustain the agriculture, such as soil and water.* *Many traditional practices that are being forgotten are recovered with the cultural values.*	*Higher* *It incorporates the cultural control, which adopts ancient practices.* *There is high compatibility with the environment and the conservation of soil and water.* *The ethical nature of agricultural production becomes important with the IPM in that nature-producer-consumer relationship.*
	Compatibility with national production regulations (CENAPE,	*High* *Regulations for the certification as organic coffee are observed to export the product with AOPEB and other*	*High* *The Municipal Committee of Ecological Production was organized based on the promoters to implement the*	*Low* *The current regulations are not observed, nobody controls how the product is obtained. Controls should be implemented.*	*High* *In general, it is compatible with the regulations regarding the innocuousness of foods, which are recovered by the Act 3525 that will*	*Low* *The institutions in charge of the control are not fulfilling their obligations (e.g. Nobody controls the introduction of citrus plants carrying canker and the disease is*

	organic production)	*organizations.* *The regulations of the CENAPE, which is organizing the Municipal Committee of Ecological Production, are not applied yet.*	*regulations of ecological production.* *There are 180 producer families and 95% of them qualify to become organic producers.*	*The recommendation of the label is not read (conventional producer).*	*regulate and promote the ecological production in Bolivia.* *With several regulations and with the New Political Constitution of the State, as well as with the regulations and good agricultural practices that the FAO and other international organizations try to disseminate among the farmers.*	*spreading).* *There are no laboratories to define situations. Currently the work is carried out intuitively or in many cases as a political favor.*
Compati-bility	***Compatibility of IPM with known agricultural practices***	*High* *Many practices already known and practiced by the old people are carried out.* *More time and dedication are required, in a few words, it is necessary to be decided.*	*Medium* *The grounds are the same, but the IPM requires more knowledge on the roots of the problems and how these can be overcome. Study, experimentation and test are required to be sure of its usefulness.* *Almost everything of the conventional agriculture is useful, but the IPM improves a lot the agriculture, although it is not so easy to put into practice, it is necessary to learn a lot of things and make the decision to do things well.*	*Medium* *It is an improved agriculture, but the grounds are the same.*	*Medium* *In general, producers try to get the highest volume of harvest and make use of all the alternatives available, mainly the most effective, immediate and cheap, such as the use of pesticides. For that reason, sometimes the IPM is not completely compatible with conventional agriculture.*	*High* *Local products used by the producers, such as plant extracts, are adopted within the IPM.* *It incorporates the cultural control, which adopts ancient practices.*
	Complexity of understanding IPM practices	*Medium* *Changing from the conventional is hard, especially when it was practiced for a long time.*	*Medium* *It is not complicated but knowing and managing new techniques, such as light and color traps, is required.*	*Medium* *Too much technical language is used, there are many words that are not understood well in the beginning.*	*Easy* *It is easy to understand when the trainers make efforts to reach the farmers with simple and appropriate language explaining the causes*	*Easy* *It is not complicated but first awareness raising should be carried out among producers using appropriate educational material.*

		It is not easy to identify pests, diagnose, know how to control them and dose pesticides. *Because of our low educational level it is hard for us to memorize, we don't read much, that is why practice helps.*	*It is not complex when there is willingness to learn and study, it is necessary to make the decision of adopting the IPM in a responsible way.*	*Paying attention and asking facilitates the understanding.*	*behind the high presence of pests, the considerable losses they cause and how this situation can be reverted working on the causes.* *It is easy when theory is accompanied by practice and joint reflection with the farmers.*	*There is more awareness on the problems it prevents, such as environmental and health problems, and this has influence for a better understanding.*
Simplicity	***Complexity to use IPM compared to the common practices***	*Medium* *The quick response that the producers want and the little information they have on the IPM, results in their choosing the use of agrochemical products.*	*Medium* *The IPM activities take time, new complementary techniques are required. One thing gives continuity to the other, an isolated practice does not work.* *It is not complex but you should be dedicated, it is necessary to do things well and in due time.*	*Medium* *Asking questions has helped.* *The manuals have been very useful in the field.*	*Medium* *Because it requires the previous preparation of inputs and other practices that are mainly preventive.* *It is very easy to use chemical products, producers frequently use to do it.*	*Medium* *The farmers have knowledge base, availability of time and patience.* *There is environmental and health awareness among producers, which motivates them to practice the IPM.*
	Costs of testing	*Low* *The inputs collected in the field or at home are cost-free.* *The preparation should be applied on time, otherwise it might be lost (most of them evaporate).*	*Medium* *The costs are low considering that all the required material is near (in the community), but it takes time and is laborious.* *Testing is cheap, because almost everything you need can be found in the field, but you should be strict, do things well and on time to see results.*	*Low* *The low cost motivates to try, because everything you need is in the community.*	*Low* *Many local inputs are used, which facilitates to test almost without cost.* *Much depends on the efforts made by the farmers and the proposals of the technicians.*	*Low* *Mainly because of the use of own inputs available in the area.*
	Simplicity of testing	*Easy* *A good education base is required to facilitate the practice.*	*Easy* *Almost all the techniques can be practiced because there are the means in the community and*	*Easy* *At the beginning it is difficult because there is no confidence, until it is tested and there are*	*Easy* *There is a high number of practices very easy to test in a practical way.* *The technicians use these to*	*Medium* *Sometimes, making a necessary product takes 3 months, that is why the producers should anticipate the situations and be*

Triability		It is necessary to arouse the curiosity of farmers and then they continue practicing.	only the knowledge to apply them is required. Many techniques can be demonstrated in a practical way and give results.	results. Then there is interest to reproduce the experience for others to see and get convinced.	demonstrate the virtues of the IPM (for example, different traps).	prepared.
	Visibility of results in tests	Easy When proper work is carried out regarding prevention, the results are evident. The waiting period of the chemical product is at least 20 days, of the organic product 5 days.	Medium There are quick results in some cases (traps). But the final result is only known when the harvest is obtained, and that takes time. (We have discontinued the use of pesticides, although the rest of the producers still know the basics about them).	Medium Sometimes the results are quick, quicker than those of the conventional agriculture.	Easy In cases such as the light and color traps, the results are immediate. However, the results take place based on the sum of the actions or techniques applied.	Medium It takes time, farmers want to see quick results, but with the IPM they are a consequence of the time spent. The farmers have to take care of many things, which might explain their desire to see immediate results. However, this attitude is changing little by little.
Observabi-lity	**Observable changes in the yield**	Difficult There are no noticeable changes in the quantity produced per hectare.	Difficult It takes time and work to apply the IPM and the yield is not always higher. Although the yield is important, it is more important for us that the product is healthy and that we don't get poisoned when producing or eating it.	Difficult The yield is lower but it can be compensated with the longer useful life of the plants.	Medium The yield is not a priority, but the quality of the product. Reaching the expected yield levels takes some time.	Medium An interesting yield is achieved if there are good conditions, that is, if there is a good start having soil with good characteristics.
	Observable changes in the quality of the product	Easy The taste of coca is sweeter, that can be quickly perceived. Tomatoes are more delicious. One more point is paid for coffee and one more Boliviano for a pound of coca.	Easy The product is comparably of better quality, this is highly appreciated by the families. It is of high quality (taste, shelf life), but it is not yet recognized in the market.	Easy Taste and shelf life (in good conditions it lasts up to 3 days more than the conventional strawberry) The size of the fruit is smaller than the conventional one.	Easy The smell and taste are indicators that allow to detect the quality. However, the visual quality of the product is not always the best, as it happens with conventional agriculture.	Easy Its good smell and taste are easily perceived. However, the difference will only be told through analysis in laboratory.

		The market does not recognize the quality of citrus fruits or vegetables.				
Re-invention	***Possibility to incorporate new ideas and improving IPM elements based on own experience***	*Easy* *Trying different dosages of bio-inputs the results were incorporated with the practice.* *We are always looking for new alternatives to tackle the problems or to improve what we already know.*	*Easy* *Many techniques have been modified by the promoters, for example, the way of preparing insecticides or the dosages for the different crops, which they disseminated later together with the results.* *New experiences are incorporated and made available for technicians and farmers, they test them and are disseminated in this way.*	*Easy* *We are always testing something new, the good results are discussed with the rest of farmers and the knowledge is available for everyone.*	*Easy* *It is known that the producers incorporate elements that arise from the practice; they do that for new crops in which they test the techniques.* *Several adaptation experiences are divulged by the producers.*	*Easy* *The farmers are constantly testing and incorporating new elements, such as the use of plant extracts, which they dose for each crop in a different way.*
Alliances	***Possibility to find allies to disseminate IPM***	*Medium* *It is not that easy, sometimes the alliances don't materialize.* *Unión PROAGRO wants its 200 member producers to be trained.* *Development Program of World Vision wants to adopt the promoters as trainers in the communities.* *The municipality was going to fund trainings in three cantons but it didn't work.*	*Difficult* *It has been difficult to find good allies. The mayor's office, which is supposed to care more about these subjects, has not done much in the last two years, and now it's worse because it is not working for two months already.* *Good alliances are being constructed with ISTAIC and AOPEB.*	*Difficult* *The mayor's office contributes almost exclusively to the training of farmers.* *It does not provide enough support to the strengthening of the association of organic producers.* *There are no other support institutions.*	*Medium* *There were difficulties at the university itself to find allies among the authorities and the professors.* *It's easier outside the university, among the professionals carrying out rural extension activities.* *There is a favorable institutional context and generalized awareness for the dissemination of the IPM.*	*Difficult* *A work group on the subject is being strengthened. ISTAIC, organizations of producers, AOPEB, Unión PROAGRO and support institutions participate in the group. The intention is to generate a publication with the systematization of the experiences developed in the area.* *The problems in the municipality hinder all coordination relations.*

Chapter 8

Discussion

In this chapter a brief presentation of what has been discussed in the papers 1-4 is given, together with a more in-depth discussion of some important issues on Acute Pesticide Poisonings and their prevention.

We saw the use of hazardous pesticides WHO class I, II and O among small-holder farmers, some of which are restricted or banned in many countries including Bolivia. The knowledge of pesticide toxicity, self-protection and proper handling was scarce as was the knowledge on organic farming. This led to frequent self-reported APPs and a depressed ChE level among the most exposed farmers compared to the less exposed farmers as seen from the baseline study (60).

Training on IPM improved farmers' knowledge, attitude and practice regarding proper pesticide use, increased the use of alternatives to pesticides and lowered the number of self-reported APPs. IPM knowledge seemed to some extent to diffuse from trained farmers to neighboring farmers improving their knowledge and practice as well, although not to the same extent as the improvement seen among the trained farmers.

According to farmers and agronomists a mainstreaming of IPM might be hampered by the more intensive labor required by IPM compared to conventional farming, and not always compensated for by a higher net revenue on the products. IPM required more skills and technical knowledge and the finding of allies for diffusion of IPM were not easy, factors of disfavor for a diffusion of IPM. However several issues, such as lower costs by not buying pesticides, healthier and more environment friendly farming with respect to local culture, the easiness and possibilities to experiment and adapt IPM to local circumstances among others, were in favor of IPM when compared to conventional farming.

8.1 Pesticide handling and reasons for acute occupational pesticide poisonings

A limited knowledge about pesticide toxicity and an inappropriate use of personal protective devices and personal hygiene when handling pesticides was seen in our and in most other surveys, (table 3 and 4).

The farmers in our surveys reported of frequent APPs after pesticide handling, and a depressed ChE was found in our baseline survey and by other (table 3). Risk factors for self-reported APPs and an affected ChE were pesticide toxicity, spraying frequency and personal protection when handling pesticides as found in our baseline study and by others (table 3).

Farmers with a low educational level and little or no agricultural training used less personal protection and complained more often of symptoms of APP as shown in two of the Plagbol studies and by others (16, 48, 56, 60, 102). This is an important factor as low educational level makes the reading and understanding of instructions and training materials difficult as stated by farmers in our focus group discussions and mentioned by others (66, 75). The limited knowledge on pesticide toxicity and handling found among retailers makes their advice questionable, which is a serious problem as retailers are often the main external source for farmers on proper pesticide handling (66, 91, 105).

People with a low socio-economic status often have a low educational level, and it has been shown that farmers with low socio-economic status more often report severe APPs, probably due to a poorer protection when handling pesticides (16).

However the opposite was seen in a study from Korea where the number of APPs seemed to increase with a higher level of education and income among the farmers (54), which might be explained by a higher use of pesticides among these farmers.

Our own experience is that the very poor farmers do not use that much pesticide as they do not have money for buying pesticides and thereby run a minor chance of suffering an APP.

Highly hazardous, banned and/or obsolete pesticides were stored on most farms. We found a mean of 180 gram of obsolete pesticides on each farm. If the same was found among other small-holders in Bolivia, more than 100 ton of obsolete pesticides from farmers storages can be added to the 377 tons already located in known storages in Bolivia by FAO (95). The finding highlights a special logistic problem as the obsolete pesticides on the farms will be difficult to collect for destruction, due to the farms being scattered all over the country and often in remote areas. The problems with obsolete pesticides are well known from other countries as well. (106-108).

8.2 Self-reported acute pesticide poisonings

We found a variation in the number of self-reported APPs in our surveys varying from 33 to 70% with one or more symptoms of poisoning during the past year (60, 102). As seen from table 3 there are also huge differences in the number of APPs reported by others.

These divergences in frequencies of APPs can be due to the unequal risk factors farmers are exposed to in the different surveys such as type of crop grown, personal protection, toxicity of the pesticides and varying pest pressure from season to season shown to be of importance in the surveys reported in table 3.

Symptoms of pesticide poisonings like headache, tiredness, trembling hands, blurred vision etc. are not ‘pesticide specific’ and could as well be due to other causes such as dehydration, exhaustion, sunstroke or other diseases. This implies that symptoms of APPs might be due to other causes than pesticides and the lack of a uniform definition of an APP is another important explanation to the different frequencies of APPs seen in the surveys.

To get a better estimate of APPs, one survey made farmers self-report APPs during a growth season after each spraying session and found that 61% of the spraying operations was associated with vaguely defined health effects, while 31% was accompanied by a least one clear symptom of an APP (49).

When requiring more symptoms to diagnose an APP, the number of poisonings registered becomes fewer. An illustrative survey is the one from India, where 83.6% of the spraying sessions was followed by one or more self-reported APPs and the number fell to 10% when three or more symptoms were required to classify the case as an APP (16).

The hospital registers are not registering most of the occupational pesticide poisonings, as they are often not that severe an do not require medical attention (35).

WHO suggested a common tool for detecting pesticide poisonings including at least three symptoms or signs and possibly a depressed ChE (24). This tool set up a matrix for diagnosing APP cases that should meet at least one criterion in each of the categories being documentation of a. exposure, b. health effects and c. causality. A distinction is made between probable and possible cases and subjective and objective symptoms, verified by health professionals, bystanders and the poisoned person (24).

The tool is best suited for clinical settings and not for field conditions where the cases of APPs are most often identified retrospectively by interviewing farmers on their past experiences. The tool can though be used for graduating the APPs into more or less severe according to class and number of symptoms as done in several surveys and recommended earlier as a tool for classification (16, 49, 51, 54, 56, 109).

8.3 Cholinesterase as a measure of poisoning by organophosphates and carbamates

A lower mean ChE level is often seen among farmers exposed to organophosphate and carbamate pesticides compared to non-exposed or less exposed farmers (table 3). A depression within the same farmer with repeated measurements during a spraying season compared to a non-spraying season is demonstrated as well (table 3).

In our baseline study we found no significant correlation between symptoms of poisoning and ChE level although the ChE-level was lower among farmers having experienced symptoms within the last month, as also found by others (46, 58-60). An explanation for this could be the time lapse from the last spraying episode until the interview and the blood test were realized as ChE could have normalized within that time. Another explanation might be that although exposure was documented in the blood tests, the poisoning did not reach 'the toxicity threshold' where symptoms of poisoning appear.

It is described that an inhibition of AChE between 50% and 60% elicits relatively mild symptoms such as weakness, headache, dizziness, nausea, and salivation with a convalescence of 1–3 days (38). An inhibition of AChE between 60 and 90% produces moderate symptoms such as sweating, vomiting, diarrhea, tremors, disturbed gait, chest pain and cyanosis of the mucous membranes which reverse within few weeks (38). At 90–100% inhibition, death from respiratory or cardiac failure occurs (38).

This explains why in most of the follow-up surveys a depression of ChE needs to be of a certain magnitude before a correlation with symptoms of poisoning is seen (34, 47, 48, 50, 57).

To explore the frequency of APPs after spraying with an acute toxic pesticide we conducted an experimental study in Nepal comparing symptoms and ChE in the same farmer whether spraying with a class II organophosphate or with an organic pesticide. The study showed no significant changes in the number of self-reported symptoms or differences in ChE level after a spraying session regardless of what the farmer used for spraying (pers com, Dea Kofoed). In this study we would have expected an increased number of symptoms and a lowered ChE when spraying with the toxic organophosphate compared to the organic pesticide.

In another experimental study in Nepal we made farmers spray with or without protective equipment. This study showed no significant difference in self-reported symptoms or ChE level before and after a spraying session whether it was with or without the use of a standardized Personal Protective Equipment (PPE) (pers com, Anshu Varma). In this study we would have expected fewer symptoms and higher ChE levels among the farmers when wearing PPE. A probable explanation to the findings in these two studies is that under normal spraying circumstances without a leaking sprayer, no spraying against the wind and using proper personal hygiene a WHO class II pesticide does not enter the body to a degree that causes an APP.

In conclusion - self-reported symptoms are not very reliable indicators of an APP if only weak and few symptoms are reported. If several symptoms and/or more serious symptoms are reported and you eventually can correlate symptoms with a decreased ChE, then the categorization of the case as an APP is more reliable.

There are several constraints for measuring ChE like the reluctance by many people to give blood for the test, the need for qualified personnel to take the blood tests, the costs of the kits, the need for laboratory facilities to analyze the tests if not using field kits and eventually the need to have zero values taken in a non-spraying season.

8.4 Global estimate on the prevalence of occupational pesticide poisoning

There are no newer reliable global estimates on the incidence of occupational APP in farmers.

It is estimated that more than 1.3 billion people are engaged in agriculture worldwide, most of them in middle- and low-income countries where 40-60% or more of the population is depending on agriculture for making a livelihood (110).

If we assume that at least half of the 570 million farms distributed globally are situated in low- or lower-middle-income countries (111), and that on an average at least one person sprays pesticides per farm, then there must be at least 285,000,000 farmers at risk of suffering an APP.

From table 3 we see a 'twelve months prevalence' of 6.4% to 10% in the estimates requiring more symptoms of APP or the person with a presumed APP being in the need of medical assistance to classify the case as a poisoning. By using these prevalence's we estimate the number of APPs to be 18 to 29 million cases per year.

If we look at the ChE levels, pesticide using farmers is seen to be affected by a lowered ChE in higher numbers and if we use these numbers in our calculations we would reach a higher estimate. Such an estimate would also include the subclinical cases.

These numbers although very speculative are not far from the earlier calculations of 25 million APPs per year (35), and having in mind the increase in pesticide use from 1990 to now a somewhat higher estimate might be even more reasonable.

8.5 Impact of teaching farmers Integrated Pest Management

As the objective of teaching IPM was originally to tackle pest resistance and improve the harvest (3, 5, 14, 73, 74), most surveys have focused on evaluating the improvement on IPM knowledge, the amounts of pesticides used, the yields and the net return (table 5).

In our studies we found that pesticide exposure probably was reduced by a decrease in the number of spraying sessions, a reduction of the toxicity of the pesticides used and an improved use of personal protection. The lowered pesticide exposure is likely to be the explanation for the decline in the number of self-reported APPs among the farmers, also seen in other studies (table 3).

Interestingly one survey found that the farmer's own confidence in using the best available protection was a more important protection against APPs, than the actual number of protective devices used (28).

We found a long-lasting impact on KAP regarding IPM among the trained farmers. This was also seen in a study from Sri Lanka showing effects on knowledge of IPM and lower pesticide use among trained farmers five or more years after training stopped (84). Another study from Thailand found 41.7% reduction in pesticide use among trained farmers that was maintained over a 4-year period after the trainings ended, but no increase in yields and no diffusion to neighboring farmers (112).

On the other hand the lasting effect of training farmers in FFS on IPM is questioned in a study from Indonesia, finding that the yields improve and pesticide costs decrease right after graduating among both trained farmers and their neighboring farmers but these effect seems to be leveling off over a time span of 9 years (113).

A review from 2014, including a meta-analysis, found a positive effect of trainings of farmers in the short to medium term (75). The meta-analysis showed a mean decrease in pesticide use by 17%, an increase in yields by 13%, and an increase in net revenues of 19% among IPM trained farmers. There was a notable variation across populations and contexts. Trained farmers increased IPM knowledge by 0.21 standard deviations and a reduction in negative environmental impact of 39% was estimated (75).

Another review from 2015 of 85 IPM projects in Asia and Africa showed a mean yield increase of 40.9% and a decline in pesticide use of 30.7% compared to baseline (10). It was assessed that at least 50% of pesticide use is not needed in most ecosystems.

These considerable differences in the studies can be explained by the different crops grown, climatic variations, pest pressure, pest resistance and the quality and scope of the trainings and follow-up (3-5, 81, 82). Some of the difference could be due to the focus of the evaluation of the IPM trainings as yields and net income might vary a lot from season to season due to climatic variations, whereas evaluations taking knowledge and practice into consideration might show a more stable picture.

In our opinion IPM can be looked at as 'good farming practices' with the inclusion of organic alternatives to minimize pesticide use. Such knowledge is however scarce among farmers in most middle- and low-income countries hampering productivity and giving rise to the APPs and pollution.

Even without pest resistance being a problem or making use of organic methods, farmers are prone to benefit from the good farming practices contained in the IPM strategy and training.

8.6 Diffusion of Integrated Pest Management

A diffusion of knowledge from trained to untrained farmers is part of the 'training of trainers principle' in IPM, as mentioned in several case-studies (3-5, 14, 73).

The decrease in pesticide exposure and self-reported APPs we saw among the neighboring farmers in the follow up survey could have been due to a diffusion of knowledge from the trained farmers, but could also have been a 'period effect' reflecting a general improvement among all Bolivian small-holder farmers.

To explore this we conducted a cross-sectional survey (survey 3) comparing trained farmers and their neighboring farmers with a control group and saw that a diffusion of knowledge and practice was likely to have taken place as not only the trained farmers but also the neighboring farmers had a higher level of knowledge and practice of IPM than the control farmers. The main difference between the neighboring farmers and the controls were having an IPM trained farmer in their village or not.

The experiences with diffusion of IPM have been mixed and few studies have been able to show a diffusion of IPM (75, 76, 79, 80, 84, 86, 112-114).

An explanation for this lack of diffusion could be that the evaluations have taken place shortly after the intervention, not giving sufficient time for the trained farmers to pass on knowledge to their neighboring farmers. A longer follow up time is suggested as we saw a continuous improvement among the neighboring farmers even years after the training of the IPM farmers had stopped in our survey.

The different results in the the surveys might also be due to the complexity of the items evaluated. As pointed out in our focus group discussions simpler knowledge and practices seem to diffuse more easily from trained farmer to neighboring farmer than more complex skills such as the preparation of natural pesticides and fertilizers. This issue has been mentioned by others as well (75, 96, 115).

An important issue is the pedagogical methods used. Barriers to knowledge transfer and adoption of IPM such as facilitators delivering training in a top-down manner, a transfer of technology approach without much reflection and discussion are mentioned (4, 5, 73, 80). We think that training in pedagogy as done by the Plagbol project is important to assure a proper diffusion not only from facilitator to farmers but further on from 'farmer to farmer' as well.

An unexpected but beneficial result from our interventions has been that several Municipalities are now paying the trained farmers to train other farmers and are including them as supervisors in agricultural matters on IPM at Municipality level (2). In favor of diffusion an not initially planned for in the Plagbol project is the inclusion of IPM as a thematic subject in ten public technical agricultural schools in Bolivia and having the Ministry of Agriculture to include IPM as a strategy for training their small-scale farmers in their extension programs, see table 6. We think these achievements can be partly explained by the awareness rising and advocacy efforts by the Plagbol project towards politicians, administrators and professionals (2).

An important obstacle for spreading IPM to other farmers in Bolivia as interpreted from the Focus Groups discussions were 'too much extra work not always being compensated for by higher yields or higher prices on the products', issues also discussed by other researchers (75, 80, 81).

However this might vary depending on the crops grown as high quality crops such as tea, coffee, coca and strawberry seem to get better prices when grown organic, whereas vegetables did not.

The distance to the bigger markets in the cities is also of importance as they have more consumers aware of a possible impact on their health from the food they eat and consumers that are willing and have the possibility to pay more for organic products (2).

One survey found the work load to be the same in IPM cotton farming compared to conventional farming (83). This is in contrast to a Bolivian master thesis comparing different farming strategies and outcome in cauliflowers finding organic farming and IPM farming to require more labor than conventional farming (116).

If pest resistance is an issue as in Indonesia where IPM trainings started (5, 73, 74), the introduction of IPM alternatives to chemical pesticides should be more likely to guarantee improved yields and become disseminated.
However as long as the apparent benefits of pesticides are more visible than their negative effects, an effective diffusion of IPM seems difficult to make happen (80, 82, 89, 117). Such a lack of easily visible benefits of IPM might also explain why farmers and agronomists found it difficult to create alliances with politicians to diffuse IPM in our FG survey.
The cost of the different extension methods is an important issue when politicians are going to prioritize which methods to support. A study found Farmer Field School training to be the most expensive per farmer but also the most effective if the goal is to make farmers adopt the complex practices of IPM (115). Visit and short trainings by extension agent were the second most expensive solution and cost-effective for extending more complex practices, while field days were the cheapest and the most cost-effective solution for stimulating simpler agricultural practices (115).
However to do a fair evaluation of the different options one could argue that a more comprehensive cost-benefit analysis must be made including the costs related to the negative health impacts, environmental degradation and pest resistance created by pesticide use (118).
In our opinion, pesticides must be seen as an important public health issue with the potential to affect not only the users but also consumers. We think an active policy promoting IPM and a banning of the highly to moderately hazardous pesticides is necessary if IPM is to become mainstreamed and a sustainable food production secured.

8.7 Challenges, strengths and limitations

To conduct research within a development project poses some challenges. A 'scientific' approach has not been common in Danish NGO development projects, although this paradigm is questioned and research is now being implemented in several development projects. The reason for this shift is probably the increasing focus on advocacy and awareness rising where research can come up with strong arguments for action whereby good development projects might have an impact on a wider scale than only in the local project areas. Apart from this, research is also able to deliver more credible evaluations of the results than generally seen in development projects.
The Plagbol surveys have created new knowledge on pesticides and small-holder farming in Bolivia in spite of difficulties such as a poor infrastructure and no reliable register information. The surveys have taken place over a long time in contrast to many other surveys where the effects of an

intervention are often evaluated shortly after the intervention stops. An important limitation was the non-random selection of the participants done by convenience, and thereby introducing selection bias. Random selection of participants was difficult as no population registers existed in the disperse project villages in the Andes. A lack of confidence is also a problem as many people, if randomly selected, would probably have denied participation in the surveys.

The neighboring farmers selected the farmers to go for IPM training and these farmers were younger, mostly men and better educated than their neighboring farmers. Such a skewed selection whether it is on gender, education or social status has also been mentioned in other surveys (73, 83, 86, 114, 119).

The non-random selection methods are seen in most surveys being part of a development project, although hampering the ability to generalize the results.

Recall bias might be introduced by using self-reported information in the questionnaires. The use of questionnaires and interviews is often preferred as observations or blood tests might be too costly in time and money. Recall bias could be of minor importance if we assume that the size of the bias is equal in the different groups studied.

Different interests and priorities between researchers and project staff was experienced in the Plagbol project and discussed by others, making research in a development project not always that easy (97).

Common conflicts include the following:

- Should the project be staffed with either with highly skilled scientists or with a staff with knowledge of local culture and language, and being respected by the community.
- Should the data collection consist of questionnaires and collection of biological material for analysis or subjective data collection with open interviews or focus group discussions easier to use among target groups often bored with too rigorous and time-consuming procedures and being suspicious to blood samples, etc.
- Should random sampling or non-random sampling of participants be used, , where non-random selection often is found easier to handle by the project staff or creates local ownership and sustainability in the project by letting the villagers choose the participants in the surveys.
- Should project planning be rigorous with fixed schedules and activities as often wanted by researchers or more flexible and able to respond to new possibilities and needs felt by target groups and staff during the project period.

Other challenges we have experienced in our projects are financial constraints in the budgets and a lack of time among the project staff to do research beside their daily work in the projects.

This has sometimes resulted in local decisions suddenly changing the approved research set-up such as fewer questions used than agreed upon, a reduced number of participants and a too tight time schedule for data collection. This has without doubt resulted in lower quality of the data and less strength in the analysis than planned, but at the same time it has created increased local ownership and more use of the results by the project staff.

The reason for changing or suggesting a given research set up by the project staff has always been a wish to save ‘time and money’. To minimize these short-comings, training on research strategy and mutual planning between researchers and staff before starting the research is highly recommended. The purpose of the research must be made clear and agreed upon from the start and the research must be adequately funded. These recommendations have only to some extent been respected in the Plagbol project.

A final important restriction for research in low-income countries has nothing with the development projects to do, but is the apparent reluctance of researchers and donors to invest in such research. This might be due to scarce funds for such research, commodities and language barriers among other things.

Due to the high occupational exposure levels significant findings and effects of preventive measures, however, are much more likely to be found by research in low-income countries. This should encourage researchers and donors to increase the research efforts to create new knowledge of global importance and strengthen the North-South research collaboration.

Chapter 7

Conclusion and Implications

Occupational pesticide poisonings among small-holder farmers in Bolivia and other middle- and low-income countries seem to be common although exact numbers varies between surveys. Risk factors for occupational pesticide poisonings are factors potentially leading to a higher pesticide exposure such as the use of highly hazardous pesticides, frequent spraying operations and insufficient personal protection and hygiene when handling pesticides.

Farmers trained on IPM are likely to increase their knowledge about pesticide toxicity and use of organic methods, while at the same time decreasing their use of highly hazardous pesticides. They also improve on safer pesticide handling and storing practices. These changes can lower the number of pesticide poisonings and the environmental pollution.

Knowledge on IPM might to some degree diffuse to neighboring farmers, but important obstacles for a mainstreaming of IPM seem to be the extra workload required when practicing IPM as this is not always compensated for by higher yields or better prices of the crops on the market. Moreover IPM techniques are, although somewhat similar to conventional farming, not that easy to learn which is also hampering the IPM diffusion.

In favor of an IPM mainstreaming is the recognized advantages on health and environment and the less input of the costly agrochemicals and the ease of adding traditional and own experiences into the IPM farming methods.

We find that educating farmers on alternatives to pesticides and a proper use of pesticides like in the IPM strategy is essential to reduce the negative health effects of pesticides. To reach this advocacy and awareness rising is needed to push for an active political intervention based on current knowledge, as market forces have not been able to find solutions to reduce pesticide use. Politicians must prioritize an effective extension system for technical support to promote IPM, consumers must be made aware of the importance of a healthy and sustainable food production and a labeling of IPM and organic grown food must be implemented. The influence of pesticide companies on government policy should be illuminated and if necessary restricted, and the most toxic WHO class I and II pesticides banned.

Ongoing monitoring of the incidence of occupational pesticide poisonings in Bolivia and elsewhere is needed to plan and evaluate extension services and other APP preventive efforts.

Studies on strategies on how best to diffuse IPM are needed as such diffusion seems to be the major hindrance for a sustainable and healthy food production.

In the coming years the Plagbol project will focus on advocacy among politicians to ban the most toxic pesticides, on consumer safety by documenting pesticide residues in food, and on awareness rising to avoid environmental pollution by the many empty pesticide containers and obsolete pesticides found in the countryside in Bolivia.

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Annex 1

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Occupational pesticide intoxications among farmers in Bolivia: A cross-sectional study.

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Abstract

Background

Pesticide use and its consequences are of concern in Bolivia due to an intensive and increasing use.

Methods

To assess the magnitude and reasons for occupational pesticide intoxication, a cross-sectional study with interviews and blood-tests was performed among 201 volunteer farmers from 48 villages in the temperate and subtropical valleys in the eastern part of the Andes Mountains in Bolivia. Of these 171 male farmers using pesticides in their agricultural production were used in the statistical analysis, including linear- and logistic regression analysis.

Results

This study documented a frequent use of the most toxic pesticides among farmers who have had almost no instructions in how to use pesticides and protect themselves against the dangers of intoxication, reflected in the hazardous practices used when handling pesticides. Symptoms of intoxications were common in connection with spraying operations. The risk of experiencing symptoms and the serum cholinesterase activity were influenced by whether or not organophosphates were used and the number of times sprayed. The experience of symptoms was moreover influenced by the hygienic and personal protective measures taken during spraying operations while these protective measures were not found to have influence on the serum cholinesterase level.

Conclusions

The study showed that occupational pesticide intoxications were common among farmers and did depend on multiple factors. Pesticide use is probably one of the largest toxicological problems in Bolivia, and a coordinated action by authorities, society and international bodies is needed to limit the number of intoxications and the environmental pollution.

Background

In Bolivia almost half of the population of 8.3 million is living on farming and related activities, contributing to 15% of the Gross National Product. The agricultural sector can be divided into two categories, one which is cash crop producing, mechanized large farms in the tropical Amazon lowlands, and the other which is small-scale farming in the subtropical valleys of the eastern slopes of the Andes Mountains and on the temperate plateau – 'the Altiplano' - 4,000 m above sea level.

In most low income countries, intensification of agriculture and to a lesser extent the public health control of vector borne diseases have lead to an increase in the use of pesticides. In Bolivia the value of the imported pesticides has increased 20% per year during the last decade, which is substantial even compared with other low-income countries (FAOSTAT data, 2004).

It is vital that the impact of this increasing use of pesticides (1) can be assessed and the information brought forward to guide governments and international bodies in the formulation of appropriate policies and to evaluate current initiatives. This documentation is lacking in Bolivia as in most other low income countries.

The studies conducted in Bolivia during the past decades have shown insufficient mechanisms to control and regulate pesticide imports and sales, lack of knowledge about handling the pesticides, rudimentary use of personal protective equipment and insufficient protective hygienic measures applied among farmers (2,3,4,5). Likewise, frequent experiences of acute intoxications among farmers when handling pesticides, easy access to pesticides leading to cases of self-inflicted intoxications in the population and pesticide residues above recommended levels in foodstuff are reported (2,3,4,5).

This study focuses on the assessment of occupational pesticide intoxications and risk factors for these among the farmers in the valleys of the eastern slopes of the Andes Mountains in La Paz County, Bolivia.

Methods

The study area and background

The study was done as part of the Plag-Bol project, the objective of which is to lower the number of intoxications and reduce the environmental pollution from pesticides. The project activities include education of health personnel in diagnosis, treatment and prevention of intoxications, the promotion of Integrated Pest Management strategies (IPM) among farmers, and a general awareness raising concerning the possible dangers for health and environment from pesticides among the public through information spread by mass-media and educational institutions.

The data presented were gathered over a four week period in March and April 2002 from 201 farmers living in 48 small villages with a total population of approximately 10,000 people. Of these, approximately 2,000 are male farmers, and our sample then represents about 10% of the male farmers, and 2% of the total population in the villages. Due to the mountainous terrain, the climate in the study area varies from temperate to subtropical making it possible to grow a wide variety of crops such as vegetables, corn, potatoes, flowers, fruits, coffee and rice, which are most often marketed in the nearby capital, La Paz. The spraying season is from October to May, although some spray throughout the year, especially the farmers growing tomatoes and flowers, crops which can be harvested several times a year.

The study was approved by the Medical Ethical Committee in Bolivia and the Bolivian National Institute of Occupational Health (INSO) and was in compliance with the Helsinki Declaration.

Design

The farmers participating in the study were from the villages where the Plag-Bol project was taking place, and the data were collected before awareness raising or any other activity took place in the project. The participating villages were selected after consultations with the local farmers´ representatives. They were known to be villages with significant use of pesticides and a good accessibility by road or river thus facilitating later project intervention activities. Farmers were invited to village meetings, where they were briefed about the study, its relevance and what health dangers the blood tests could pose. They were asked to volunteer for the study and then interviews and tests were carried out on 201 farmers of which 19 were females. They had a mean age of 36 years (range 15-79), had been working for 20 years in agriculture (range 1-60), and cultivated on average 1.6 hectares of land (range 0-11). All participants signed an informed consent form before the interviews were conducted and the blood samples were taken.

The interviews and blood tests were used to evaluate a possible influence on the health of the farmers by pesticide use and to identify risk factors for intoxication. A maximal number of persons of 250 was estimated as realistic for the statistic purpose of the investigation based on knowledge of symptom frequency and cholinesterase measurements from a former study (3); for a 25% fraction in the smallest exposure group and a 20% symptom score this gave an 80% power of detecting an odds-ratio of 2.4, while a difference of 0.7 IU of cholinesterase could be detected with the same power. These figures were thought as relevant minimal detectable differences.

Interview forms used in Bolivia, Denmark and the US were the basis for a questionnaire consisting of closed and open-ended questions, including i) age, sex, education, family status, the suffering from any diseases, smoking habits etc., ii) the size of cultivated land, crops grown, pest affecting the different crops and the way to deal with them; iii) knowledge, attitudes and practice when buying, handling and storing pesticides; and iv) perceived health impact, perceived dangers of pesticides, experiences with acute pesticide poisonings and toxic symptoms in connection with spraying. When symptoms were assessed the interviewed was asked if he had felt ill in connection with spraying during the past year, and if the answer was yes, he was asked to specify, which symptoms he had experienced. The interviewer could mark symptoms on a pre-elaborated list or add symptoms if they were not on this list.

The questionnaire was pilot tested and adjusted when necessary and the survey was conducted by trained health professionals and agronomists in order to control inter-observer variability.

The blood tests were taken by the laboratory personnel from the National Institute of Occupational Health in La Paz at the time of the interviews; the participants signed an informed consent before blood-tests were taken. The tests were centrifuged on site, the serum frozen and transported for analysis of serum cholinesterase activity (ChE) at the laboratory at Odense University Hospital, Denmark. The ChE activity was measured by a spectrophotometric method where ChE activity is used in the first step of a reduction of potassium hexacyanoferrate leading to a color change that can be measured with a variance below 2.3% within the same set of analysis. The measurements were given in kilo units per liter (kU/L) (6). The ChE activity is known to be lowered by intoxication with organophosphates and carbamate pesticides and to be influenced by weight, sex, age, liver-diseases and the use of contraceptive pills (6).

Based on the interviews with the farmers the WHO toxicology classification was used to identify and classify the different pesticides mentioned (7).

Data analysis

Of the 201 farmers interviewed, 186 farmers used pesticides, of which 171 were males. In the analysis of occupational risk factors for a depressed ChE activity this group of 171 farmers was used, excluding one with a missing blood test. One hundred and fourteen of the 171 farmers had been spraying within a month prior to the interview, and this group of 114 male farmers was used to test risk factors for the experience of symptoms in connection with spraying (symptoms during or immediately after a spraying operation).

The first group of risk factors tested for was the number of times sprayed in the past month and the use of organophosphates (OPs) or not during the past month. These two variables were aggregated into one coded 0=no spraying, 1=spraying only pesticides other than OPs, 2=spraying 1-3 times with OPs, 3=spraying >3 times with OPs. It was assumed that the group with the heaviest exposure to pesticides would be the group having sprayed more than three times with OPs, and that this would be reflected in the experience of symptoms and in the blood test.

The second group of factors tested was the protective behaviors performed when spraying. They were tested one by one and in an aggregated variable including the use of personal protective equipment (using plastic poncho, mask, gloves or boots while spraying), the level of personal hygiene measures (changing clothes, washing hands, washing body after spraying; refraining from eating/chewing coca leaves while spraying), avoiding re-entry into a newly sprayed field, refraining from blowing/sucking the nozzle of the knapsack sprayer when cleaning it and reading instructions on the pesticide container before use. The aggregated variable was expressed as a score where each protective behavior counted 1 point if performed. The participants were divided into four groups of appropriated size, expressing the number of protective behaviors they performed when handling pesticides (0-3, 4-5, 6-7 and >7).

The possible confounders as age, body mass index (BMI), smoking, years of farming and educational level were analysed one by one and all together. Women were excluded because of a known influence of sex on ChE activity and owing to the few women participating in the study. Data of alcohol use was not included in the questionnaire. Alcoholism (a daily intake of alcohol) could be a confounding factor, but profound knowledge from these areas tells us that alcohol consumption on a daily level is almost unknown for economic and traditional reasons. We did however ask for alcohol consumption during the last 24 hours prior to the blood tests were taken, and found no reason for excluding any of the farmers due to this.

Data were entered and analyzed in the statistical program STATA 8.0. Frequency analysis, $\chi 2$-test, t-test, non-parametric test, linear regression and logistic regression were used in the analysis.

Results

Pesticides used

The ten most common pesticides used by the farmers, according to the WHO classification (7), are listed in Table 1. Insecticides were used by 97% of the farmers (mainly organophosphates 88%, pyretroides 48%), followed by fungicides (63%) and herbicides (31%). Aldrin, dimethoate and parathion were used, though not allowed to be imported and restricted or banned through international treaties signed by Bolivia.

Pesticide handling

The level of knowledge among the farmers is seen from Table 2, where answers about factors with a possible influence on intoxication of humans and pollution of the environment when handling pesticides are listed.

Twenty five percent of the farmers had received some instructions on how to use pesticides, mainly from salesmen; and seventy four percent told that they did read the instructions on the pesticide containers before use. However, the meaning of the color marked on the pesticide containers signalizing the toxic potential of that specific pesticide was unknown to seventy one percent of the farmers.

Symptoms and risk factors

Seventy percent of the male farmers using pesticides reported having experienced symptoms of intoxication in connection with one or more spraying sessions during the last year, while forty five percent of those who have been spraying past month did experience symptoms. The most frequent symptoms mentioned were headache, dizziness, tiredness, blurred vision and vomiting, Figure 1.

In an aggregated variable, expressing the number of times sprayed and whether or not OPs were used, the experience of symptoms in connection with spraying was found to be depending on the degree of pesticide exposure as seen in Table 3. When comparing the experiences of toxic symptoms among those who had sprayed >3 times in the previous months with those who had sprayed 3 times or less an OR of 3.58 (95% CI 1.44-8.92) was found after controlling for the number of protective behaviors practiced. Analyzing for the use of OPs or pesticides other than OPs and controlling for the number of protective behaviors practiced, an OR of 2.96 (95% CI 0.96-9.12) for having symptoms after spraying with OPs was found.

The number of protective behaviors performed while handling pesticides also showed an influence on the risk of experiencing symptoms after spraying – the more protective behaviors performed the less chance of experiencing toxic symptoms after spraying, as can be seen from Table 2. When analyzing the protective behaviors one by one, controlling for the type of pesticide used and the number of times sprayed, 'no use of gloves' (OR 2.87, 95% CI 0.90-9.11), 'no use of a mask' (OR 2.72, 95% CI 0.96-7.73), 'the habit of blowing/sucking the nozzle of the knapsack sprayer when obstructed' (OR 4.00, 95% CI 1.70-9.45) and 'not reading the instructions on the container before using the pesticide' (OR 3.24, 95% CI 1.19-8.87) showed elevated OR for the experience of symptoms and seemed to have greater importance for the experience of symptoms than the rest of the assumed protective behaviors.

Possible confounders like age, BMI, years of farming and educational level were not shown to have any significant influence when taken into the analysis. Smoking had, but as it only increased OR without affecting the significance of the analysis, and resulted in some very broad confidence intervals due to the few smokers and the limited size of the study, it was not included in the analysis. The educational level (being an analphabet, up to six years of public school, 6-10 years of public school, having a technical or a higher education) was shown to have an influence on the number of protective measures realized when spraying, (p=0.04, Spearmann rank correlation test).

Cholinesterase activity and risk factors

In the aggregated variable, expressing the number of times sprayed and whether or not OPs were used, the mean ChE activity was found to be depending on the degree of pesticide exposure as seen in Table 4.

Analyzing the number of times sprayed, controlling for the number of protective behaviors performed and BMI, a ChE activity of 8.36 kU/L for those who have not being spraying was found, compared to a ChE activity of 7.60 kU/L for those who

have being spraying from 1-3 times (p=0.03) and a ChE activity of 7.12 kU/L for those who have being spraying >3 times (p<0.01).
Comparing the group who has been spraying with OPs with the group who has not, controlling for the number of protective behaviors performed and the BMI, a mean ChE activity of 7.11 kU/L for those who have sprayed with OPs compared to a mean ChE of 8.03 kU/L for those who have not, was found (p<0.01).
The number of protective behaviors did not influence the ChE activity significantly. The only significant protective behavior was reading instructions on the pesticide container before use or not, ChE activity 7.46 kU/L versus 6.84 kU/L (p=0.02), and controlling for whether or not OPs were used, the number of times sprayed, and BMI.
BMI was shown to be a confounder of the ChE activity and was taken into the analysis, but other potential confounders like age, smoking, years of farming and education showed no effect on results and were not included in the analysis presented in Table 4.
The mean ChE activity among those with symptoms after spraying past month (n=51) was 7.07 kU/L compared to a mean ChE activity of 7.46 kU/L among those without symptoms after spraying (n=63) (p=0.14).

Discussion

This study documented the use of very toxic pesticides among farmers. The farmers had received almost no instructions about the dangers of pesticides and preventive measures to protect themselves and the environment leading to very hazardous practices when handling pesticides. Possible symptoms of intoxications and a depressed ChE activity after spraying sessions seemed to be common and were related to spraying intensity, spraying with OPs or not and the number of protective behaviors performed when handling pesticides.
The situation where more than seventy five percent of the farmers used pesticides either not registered for use in Bolivia or restricted by international conventions signed by Bolivia needs attention (9-13). The reasons might be their free availability owing to smuggling and the control measures regarding import and sales of pesticides not being enforced (2,3,14). Pesticides of all kind are sold to everyone on the street and in shops, where the salesmen mostly operate without a license and do not comply with the Bolivian law regulating the sale and marketing of pesticides (2,3). Pesticides

are often kept next to foodstuff and only to a limited extent locked up in a safe place. The result is frequent intoxications, not only in occupational circumstances but also due to accidents and self-harm. From the Plag-Bol study it was reported, based on review of hospital registers and interviews with farmers, that pesticides are by far the most common agent for suicidal attempts and that ninety two percent of the fatal intoxications with pesticides were self-inflicted (15).

To restrict the accessibility, pesticides should be kept locked up, license to pesticide dealers should be controlled, farmers could be licensed allowing only persons with license to buy and use pesticides, and a positive list with a restricted number of pesticides excluding the most toxic ones could be established as suggested by some authors (16,17). This would have an effect not only on occupational intoxications, but also suicidal and accidental intoxications would be minimized (18). Studies have shown that by applying alternative and ecologically based methods, pesticide use can be decreased by at least fifty percent without reducing the yield (19,20), and this might be one of the possibilities for controlling this increasing prevalence of pesticide poisonings.

The frequency of self reported work related symptoms of pesticide poisonings was higher than found in previous Bolivian studies from 1989 and 2000, which showed a lifetime experience of poisonings of 10.5% and 48% respectively (3,4). A study from Nicaragua reported a frequency of 11% of responding farmers having experienced symptoms of intoxication after spraying during the last month, 25% in the last 12 months and 48% at one point in time (8). The variation between the studies might be due to differences in crops cultivated, pest pressure, spraying intensities and toxicity of the pesticides used. Recall-bias due to different recall periods applied might be another explanation. The difference between the Bolivian studies might also reflect the significant increase in the use of pesticides in Bolivian agriculture over the last decade.

The knowledge of how to handle pesticides and the use of protective measures were poor in the actual study, as seen from Table 2, and also found in earlier studies from Bolivia and other low-income countries (2,3,21-23). One possible explanation could be the lack of access to information, and a general, low level of education leaving many as functional illiterates. Although seventy five percent of the farmers reported reading the information on the pesticide containers, clearly, they did not understand the information on the label or they only read information that enabled them to apply it more efficiently, and not for safety reasons. The limited use of personal protective equipment might be due to the lack of availability, lack of money to buy or the inappropriateness of protective measures when used in hot climates as found in other studies (24,25), and pointed out by farmers to the Plag-Bol project (personal communication).

The significant 'dose - response' associations as seen in this study between the number of times sprayed/the use of OPs or not/the number of protective behaviors realized while handling pesticides on one hand and the experience of symptoms of intoxication and the finding of changes in ChE activities are also found in other studies from low-income countries, where the use of some personal protective equipment, a certain level of personal hygiene when spraying, and knowledge of pesticide dangers have been shown to prevent toxic symptoms and/or a depressed ChE activity (1,21-23,26). Some studies do not find the relationship between protective measures undertaken and symptoms of intoxication (19,27), probably reflecting the difficulty in analyzing a single occupational risk factor, without taking other closely related factors into account at the same time. Therefore it might be sounder to aggregate various closely related protective factors into a score as we did in the actual analysis. One might argue that this takes away the idea of identifying specific risk factors to be targeted in an intervention, but only targeting e.g. one risk factor like 'reading the label on the pesticide containers before use' make little sense, if you do not target other important risk factors like personal hygiene measures, the use of personal protective equipment, reentry practices etc., as they all might influence the risk of having an intoxication.

The associations of symptoms and ChE levels with a higher frequency of pesticide use could reflect a cumulative effect of repeated exposure, but it could also be explained simply by the fact that people who have used pesticides more often have had more opportunity to develop acute symptoms and/or a lowered ChE level.

The lack of association between the number of protective measures taken during spraying operations and the ChE activity could be due to a too large interval between exposure and sampling of the blood tests, as the level of ChE activity returns to normal within days to weeks after exposure to organophosphates, and can thus only serve as a measure for fairly recent exposures (6). Information bias might also explain this lack of association, if people claim to have realized protective behaviors without really having done it.

The time interval between spraying and the blood test taken might also explain the lack of significant correlation between symptoms and serum ChE levels, although the farmers without symptoms did have a higher mean level. A better indicator would have been red blood cell cholinesterase activity as a marker of biological effect, whereas serum ChE is a marker of exposure.

A limitation of the study is the lack of possibility to differentiate between the seriousness of the intoxications experienced within the last month, as we did not ask for the number and seriousness of the symptoms experienced. Neither do we have data from a medical examination, as farmers mostly do not seek treatment for these normally less serious intoxications with symptoms lasting for only hours to a day. The symptoms mentioned by the farmers like headache, dizziness, tiredness, blurred vision, vomiting, salivation and muscular weakness are not specific and might, in some of the cases, be due to other causes than pesticide poisoning. Another limitation is the non-random selection using volunteers attending a meeting in the villages. This may decrease the ability of the study to generalize the findings to other regions, but should however not hamper the validity of the data. Years of experience of working among Bolivian farmers, indicate to the authors that the group participating in this study seemed to be quite typical of the small-scale farmers from these areas.

Due to inter- and intra-individual variance the ChE values must be interpreted with caution, and a normal variation of ChE for a population is often claimed to be too broad for any practical use, whereas the interpretation of individual values demands at least two measures to be taken, where one 0-value must be taken when the person has not been exposed to pesticides for some time. On a group level in an epidemiological study, we think however that it is possible to compare the mean serum ChE activity of different groups with different exposure circumstances, assuming that individuals with different basis activity of ChE are evenly distributed within the groups (6).

Conclusions

The study showed that occupational pesticide intoxications were common among farmers and were related to the frequency of spraying, the use of organophosphates and the number of protective measures undertaken by the farmers when spraying. Pesticides of the most toxic classes were widely sold and used, also those banned or restricted by international conventions and laws. The farmers had very little

knowledge about the dangers of pesticides and the benefit of protective measures when handling pesticides.
As the use of pesticides probably is one of the most important toxicological problems in Bolivia, a coordinated action by authorities, society and international bodies, including pesticide producing countries, is urgently needed to be able to limit the number of intoxications and pollution of the environment.

Competing interests

The authors declare that we have no competing interests.

Authors' contributions

EJ was the leader of the research. He contributed to all phases in the research project from conception and design, the acquisition and analysis of data and the writing of the manuscript.

RCM contributed to the conception and design and the acquisition of data.

GCA contributed to the conception and design and the acquisition of data.

OH contributed to the conception and design and the acquisition of data.

FL contributed to the conception and design, the acquisition of data and the revising of the manuscript for intellectual content.

JB contributed to the design, the analysis of data and the revising of the manuscript for intellectual content.

FK contributed to the analysis of data and the revising of the manuscript for intellectual content.

All authors have given their final approval of the version to be published.

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Figure 1: Symptoms experienced by farmers in connection with spraying pesticides within the last year (n=128)

Tables

Table 1 - Classification of pesticides used by farmers, the ten most used active ingredients and their characteristics (n=171)

Active Ingredient	Used by percent of farmers	Toxicological classes*	Chemical class	Classification by main use
Methamidophos	69 %	Ib	Organophosphate	Insecticide
Sulphur	40 %	U		Fungicide
Propenophos	34 %	II	Organophosphate	Insecticide
Cypermethrim	26 %	II	Pyretroide	Insecticide
Spinosad	25 %	U		Insecticide
Propineb	25 %	U		Herbicide
Parathion	23 %	Ia	Organophosphate	Insecticide
Dimethoate	16 %	II	Organophosphate	Insecticide
Permethrin	15 %	II	Pyretroide	Insecticide
Lambda cyhalotrin	11 %	II	Pyretroide	Insecticide

* Ia extremely hazardous, Ib highly hazardous, II moderately hazardous, III slightly hazardous, U active ingredient unlikely to present any harm in normal use, O obsolete (WHO classification).

Table 2 - Factors of importance for intoxications in humans and pollution of environment when handling pesticides (n=171)

Factor	% positive answers
Using gloves when handling pesticides	16 %
Using boots when handling pesticides	16 %
Using a plastic poncho when handling pesticides	3 %
Using a mask when handling pesticides	17 %
Washing hands after handling pesticides	69 %
Washing the whole body after handling pesticides	54 %
Changing clothes after handling pesticides	47 %
Chewing coca, smoking or eating during a spraying session	15 %
Spraying less than one day before harvest	25 %
Spraying products after harvesting and before taking them to the market	19 %
Entering a field the same day is sprayed	27 %
Blowing or sucking the nozzle of the knapsack sprayer when obstructed	49 %
Mixing pesticides at the borders of rivers or ponds	35 %
Washing knapsack sprayer in or at the borders of rivers or ponds	30 %
Throwing empty pesticide containers in the fields or into the rivers	72 %
Using pesticides as medicine for skin infections in humans (mainly scabies)	16 %
Keeping pesticides locked up	8 %

Table 3 - Odds Ratio (OR) for having experienced symptoms of acute pesticide poisoning after spraying past month according to exposure status among male farmers (n=114)

	%	Unadjusted		Adjusted*	
		OR	95% CI	OR	95% CI
Sprayed only pesticides other than organophosphates (OPs) past month	22	1(ref)	-	1(ref)	-
Sprayed from 1-3 times with OPs past month	45	2.04	0.70 - 5.99	1.91	0.58 - 6.30
Sprayed more than 3 times with OPs past month	33	6.09	1.96 - 18.97	5.97	1.63 - 21.96
>7 precautions taken when handling pesticides	17	1(ref)	-	1(ref)	-
6-7 precautions taken when handling pesticides	33	5.63	1.37 - 23.06	5.15	1.17 - 22.67
4-5 precautions taken when handling pesticides	32	4.17	1.01 - 17.18	5.19	1.15 - 23.42
0-3 precautions taken when handling pesticides	18	10.83	2.25 - 52.20	13.88	2.60 - 74.11

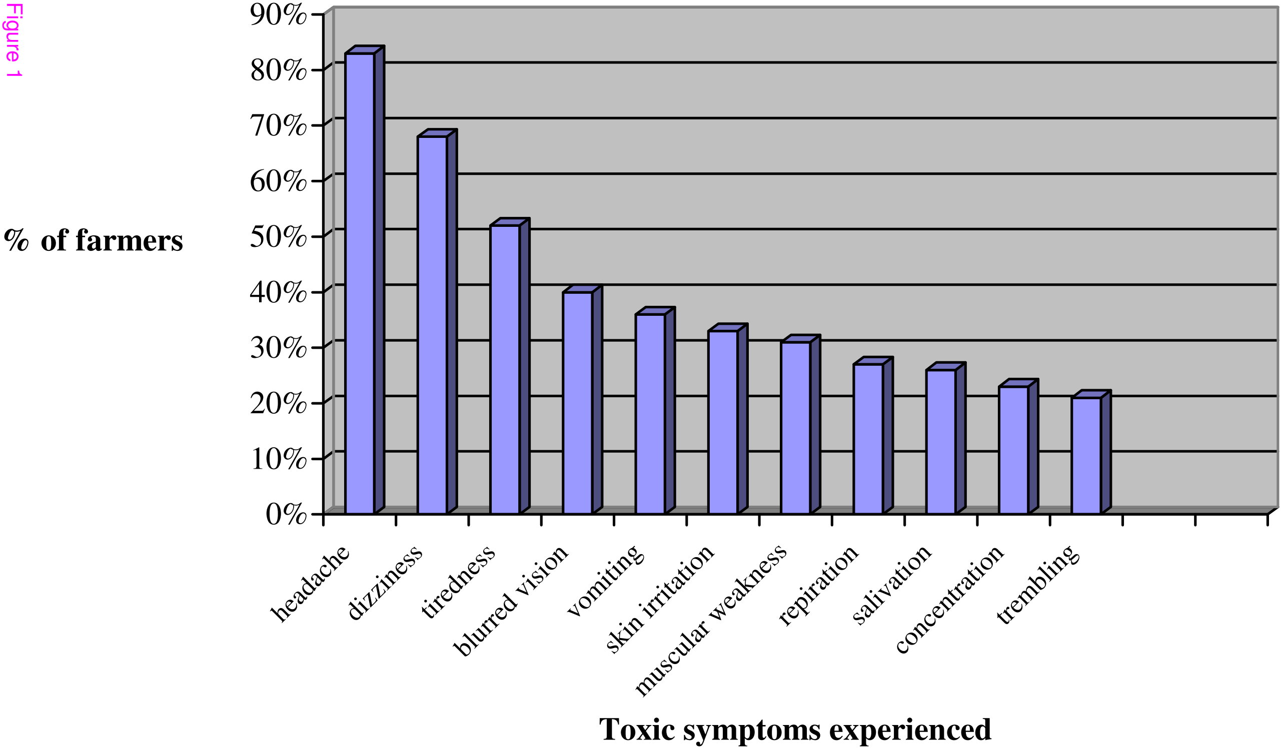
Logistic regression analysis, * the OR were mutually adjusted.

Table 4 - Serum cholinesterase activity according to exposure status past month and Body Mass Index among farmers (n=170)

	%	Mean ChE activity kU/L	Unadjusted		Adjusted	
			Coefficient	95% CI	Coefficient	95% CI
Not having sprayed during the last month	22	8.36	-	-	-	-
Sprayed only with pesticides other than OPs	17	7.60	-0.76	-1.46 to -0.06	-0.86	-1.64 to -0.09
Sprayed from 1-3 times with OPs	34	7.34	-1.02	-1.62 to -0.43	-1.19	-1.84 to -0.53
Sprayed more than 3 times with OPs	27	6.84	-1.56	-2.15 to -0.90	-1.62	-2.31 to -0.92
Constant			8.36	7.90 - 8.82		
>7 precautions taken when handling pesticides	18	7.53	-	-	-	-
6-7 precautions taken when handling pesticides	30	7.47	-0.07	-0.82 - 0.68	-0.06	-0.78 - 0.66
4-5 precautions taken when handling pesticides	33	7.51	-0.02	-0.76 - 0.72	-0.22	-0.92 - 0.48
0-3 precautions taken when handling pesticides	19	7.45	-0.08	-0.90 - 0.74	-0.08	-0.85 - 0.69
Constant			7.53	6.93 - 8.13		
BMI>25	73	8.00	-	-	-	-
BMI≤25	27	7.23	-0.77	-1.26 to -0.27	-0.49	-1.0 - 0.02
Constant			8.0	7.58 - 8.43		
Constant					8.97	8.13 - 9.80

Linear regression analysis, the OR were mutually adjusted.

Figure 1



% of farmers
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
headache
dizziness
tiredness
blurred vision
vomiting
skin irritation
muscular weakness
repiration
salivation
concentration
trembling
Toxic symptoms experienced

Annex 2

Photos 1: Sale, use, storage of Pesticides


Success
CUIDADO


Baygon
Raid
Folidol


METAFOS
(metamidofos)
INSECTICIDA
INSECTICIDA AGRICOLA
FARMEX S.A.
ALTAMENTE TOXICO
VENENO
Tamaron
600 SL
ALTAMENTE PELIGROSO
TOXICO
Tamaron 600 SL
(Metamidophos)
Bayer
ALTAMENTE TOXICO
VENENO

Annex 3

Photos 2: Training on IPM

PLAGBOL
PLAGUICIDAS-BOLIVIA
1 NO dejar fumigar a mujeres embarazadas o que estén dando de lactar a sus hijos.
2 Utilizar los plaguicidas (menos venenosos), los de etiqueta azul y verde.
3 Guardar los plaguicidas en sus envases originales y NO en otros.
PREPARANDO EL FUTURO DE LA VIDA
AMBIENTES SALUDABLES PARA LOS NIÑOS
4 NO botar al río o a la chacra los envases vacíos de plaguicidas.
5 NO dejar que
tengan contact
plaguicidas y
en un lugar seg
alle Claudio Sanjines s/n MIRAFLORES Telf. Of. 2245414 - 2244881 - 2245432 FAX 591-02-245414 Casilla #1832 e-mail; inso@
La Paz - Bolivia
DIALOGOS
care
MINISTERIO DE SALUD Y DEPORTES
PCDSMA
Programa de Cooperación Danesa al Sector Medio Ambiente

Después de años de usar plaguicidas
se pueden producir problemas más serios:
en los nervios,
los pulmones,
paralisis,
los niños pueden nacer enfermos o con malformaciones
No debes usar plaguicidas con etiqueta roja y amarilla porque son los más peligrosos. En caso de extrema necesidad se puede usar los productos con etiqueta azul y verde, tomando todas las precauciones para evitar envenenarse.
No compres ni uses plaguicidas que se venden en la calle porque no tienen envase sellado ni etiqueta que indique su toxicidad

Annex 4

DIALOGOS DANIDA

CARE BOLIVIA

INSTITUTO NACIONAL DE SALUD OCUPACIONAL

PROYECTO PLAGBOL **Nro** ☐

Municipio ____________

ENTREVISTA A LOS AGRICULTORES

Nombre del entrevistador:___________________________ Fecha de la entrevista ____________

Nombre del entrevistado ___________ / ___________ / ___________

Lugar de la entrevista: Comunidad/Colonia ______________

A. Datos personales

1. Que edad tienes?________
2. Estado civil 1. Casado ☐ 2. Soltero ☐ 3. Concubino ☐ 4. Otro ☐
3. Sabes leer 1. Si ☐ 2. No ☐ 4. Sabes escribir 1. Si ☐ 2. No ☐
4. Que nivel de educacion tienes:
   1. Analfabeta ☐ 2. Primaria ☐ 3.Secundaria ☐ 4.Técnica ☐ 5. Universitari ☐
5. Cuantos años has trabajado en la agricultura?________
6. Actualmente sufres de alguna enfermedad? 1. Si ☐ 2. No ☐
7. Si la anterior respuesta es si, indique cual enfermedad? ______________________________
8. Actualmente estás tomando algún medicamento ? ☐ 1. Si ☐ 2. No
9. Si la anterior respuesta es si, indique que medicamento?

   ____

10. Fumas a diario ? 1. Si ☐ 2. No ☐ 3. A veces ☐

B. Compra de plaguicidas y nivel de instruccíón

11. De donde compras los plaguicidas? __________________________________
12. Cuando compras un plaguicida recibes algúna información sobre el peligro que tiene?
    1. Si ☐ 2. No ☐ 3. A veces ☐
13. Cuando compras un plaguicida recibes instruccion del vendedor, sobre como se usa y para que sirve?
    1. Si ☐ 2. No ☐ 3. A veces ☐

14. Los frascos de plaguicidas tienen etiqueta cuando los compras?

1. Si ☐ 2. No ☐ 3. A veces ☐

15. Cuando compras un plaguicida lees las etiquetas? 1. Si☐ 2. No ☐ 3. A veces ☐

16. Has participado en algún cursillo sobre el uso y manejo de plaguicidas?

1. Si ☐ 2. No ☐

17. Cuantas veces has participado en estos cursillos? ....

18. Eran cursillos de? 1. Horas ☐ 2. Un día ☐ 3. Varios días ☐

19. Cuando recibiste un cursillo la ultima vez? ....

20. Mediante que organizacion recibiste el cursillo?______________________________

21 Que has aprendido en el/los cursillos a los que asististe ?

____

22. Que te faltaria o gustaría aprender?

____

____

C. Datos de los cultivos sembrados, uso de plaguicidas y opiniones sobre su accionar y sus alternativas

23.Actualmente cuantas hectarias estás sembrando? _______________________

24.Quienes te ayudan en el trabajo diario en la finca? ______________________

25.Quienes te ayudan cuando con las fumigas?_____________________________

26.Cuales son tus 5 principales cultivos en donde usas plaguicidas? Y Que cantidad sembrada tienes?

Cultivo	**Hectarias sembradas**
1.________	1.________
2.________	2.________
3.________	3.________
4.________	4.________
5.________	5.________

27.Que plaquicidas y con que frecuencia los utilizas en tus cultivos principales?

Cultivo	**Plagas**	**Plaguicidas usados**	**Fumigaciones al año**	**Cuanto tiempo fumigas**
1.________	1.________	1.________	1.________	1.________
	2.________	2.________		
	3.________	3.________		

2.________	1.________	1.________	2.________	2.________
	2.________	2.________		
	3.________	3.________		
3.________	1.________	1.________	3.________	3.________
	2.________	2.________		
	3.________	3.________		
4.________	1.________	1.________	4.________	4.________
	2.________	2.________		
	3.________	3.________		
5.________	1.________	1.________	5.________	5.________
	2.________	2.________		
	3.________	3.________		

28.Piensas que el uso de plaguicidas se podria disminuir en algunos cultivos sin que se perjudique tu cosecha?

1. Si ☐ 2. No ☐ No Sé /N.R ☐

29.Si la respuesta anterior es es si, como se podría disminuir?

____

____

30.Conoces algunos metodos alternativos/ecologicos para el control de las plagas?

1. Si ☐ 2. No ☐

31.Si la respuesta anterior es sí , indique que métodos conoce

____

D. La mezcla y la fumigación

32.Estas usando protección personal cuando preparas el caldo? 1. Si ☐ 2. No ☐

33.Que tipo de protección estas usando (puede seleccionar varias respuestas)?

1. Camisa manga larga ☐ 2. Pantalon largo ☐
3. Guantes ☐ 4. Sombrero ☐
5. Botas ☐ 6. Delantal cuero/tela ☐
7. Mascarrilla con filtro ☐ 8. Mascarilla sin filtro ☐
9. Otros ☐

34.Estas usando protección personal cuando fumigas? 1. Si ☐ 2. No ☐

35.Que tipo de protección estas usando (puede seleccionar varias respuestas)?

1. Camisa manga larga ☐ 2. Pantalon largo ☐
3. Guantes ☐ 4. Sombrero ☐
5. Botas ☐ 6. Delantal cuero/tela ☐
7. Mascarrilla con filtro ☐ 8. Mascarrilla sin filtro ☐
9. Otros ☐

36.Sabes que significan los colores de las etiquetas y sabes cuales son son?

____

37.Cual es el más peligroso? _____________________________

38.Cual es el menos peligroso? _____________________________

39.Estas haciendo alguna higiene personal cuando manejas plaguicidas? 1. Si ☐ 2. No ☐

40.Si la anterior respuesta es si que estas haciendo (puede seleccionar varias respuestas)?

1. Lavar las manos inmediadamente despues de mezclar y fumigar ☐
2. Lavar las manos antes de comer ☐
3. Lavar las manos antes de fumar ☐
4. Lavar las manos antes de orinar ☐
5. Lavar el cuerpo inmediadamente despues de fumigar ☐
6. Cambiar la ropa inmediadamente despues de fumigar ☐
7. Otros (cual?)____

41.Pigchas,comes o fumas mientras fumigas en la chacra? 1. Si ☐ 2. No ☐

42.Que tiempo antes de la cosecha estas fumigando?(Marcar con una cruz)

	horas	**dias**	**semanas**
Cultivo 1	....	....	....
Cultivo 2	....	....	....
Cultivo 3.	....	....	....
Cultivo 4	....	. ...	....
Cultivo 5.	....	....	....

43.Estas fumigando los productos antes de llevarlos al mercado? 1. Si ☐ 2. No ☐

44.Si la anterior respuesta es sí, indique que productos

____

____

45.En Total cuantas veces has fumigado durante el ultimo mes?___________________________

46.Avisas a otros cuando fumigas para que no entren al terreno fumigado?

1. Si ☐ 2.No ☐ 3. A veces ☐

47.Estás fumigando según: 1. Planificación☐ 2. Necesidad ☐

48.Qué plaguicidas has usado en el ultimo més y cuando ?

Cuales	**Cuando**
1.-	....
2. .-	....
3. .-	....
4. .-	....
5. .-	....

49. A que tiempo de fumigar vuelve a ingresar al terreno fumigado? (Marque con una cruz)

	el mismo día	al día siguente	después de 2 días
Cultivo 1.	....	....	....
Cultivo 2.	....	....	....
Cultivo 3.	....	....	....
Cultivo 4.	....	....	....
Cultivo 5.	....	....	....

50.Que equipo utilizas para fumigar?

1. Mochila ☐ 2. Equipo adaptado☐ Cual......................... 3.Otros ☐ Cual.......................

51 Revisas tu mochila antes de fumigar? 1. Si ☐ 2. No ☐ 3. A veces ☐

52 Si la respuesta anterior es es si, como lo revisas?

____53

.Soplas las boquillas de la bomba cuando se obstruyen? 1. Si ☐ 2. No ☐

3. A veces ☐

54 Donde preparas el caldo (puede seleccionar varias respuestas)

1. En la casa ☐ 2. En el terreno ☐ 3. Cerca a una fuente de agua ☐

4.Otros ☐

55.Como estas controlando las dosis de la mezcla?

1. Lo pruebas 2.☐ 2. Lo mides con cuchara ☐ 3. Lo mides con tapa ☐

4. Lo mides con copa ☐ 5. Según experiencia ☐

56.Mezclas varias tipos de plaguicidas en una sola preparación?

1. Si ☐ 2. No ☐ 3 .A veces ☐

57.Si la respuesta anterior es es si, indique que plaguicidas mezcla?

____

58.Donde guardas los plaguicidas? (puede seleccionar varias respuestas)

1. Dentro de la casa ☐ 2. Fuera de la casa ☐

3. Bajo candado ☐

59.Que haces con los envases vacìos de los plaguicidas ? (puede seleccionar varias respuestas)

1. Los usas para guardar alimentos/agua ☐ 2. Los entierras ☐

3. Los quemas ☐ 4. Los bota a la basura ☐ 5. Los boto al rio ☐

60 Que haces con el caldo que sobra ?(puede seleccionar varias respuestas)

1. Lo botas al rio 2. ☐ botas al terreno ☐3. Lo entierras ☐

4. Los bota a la basura 5. ☐nca sobra ☐

61 Lavas el equipo de fumigar despues de usarlo? 1. Si ☐ 2. No ☐ 3. A Veces ☐

62 Si la respuesta anterior es sí, donde lo lavas (puede seleccionar varias respuestas)?

1. En el rio ☐ 2. En el vertiente ☐ 3.Cerca de fuente de agua ☐

4. En el terreno ☐ 5. En la casa ☐

<u>E. Conocimientos de los efectos adversos a la salud ocasionados por los plaguicidas:</u>

63 Crees que los plaguicidas pueden tener efectos dañinos a tu salud?

1. Si ☐ 2. No ☐ 3. No se ☐

64 Si Conoces algunos efectos dañinos a la salud podrías mencionar algunos?

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65.Para Usted una intoxicación aguda por plaguicidas significa:– (puede seleccionar varias respuestas)

1. Deja a la persona muy mal, salivando, con calambres, y necesita de ayuda ☐
2. Puede dar pocos sintomas como mareo y dolor de cabeza ☐
3. Puede afectar solo la respiración ☐
4. Puede afectar solo la piel de las personas ☐
5. Puede afectar solo las uñas y los ojo ☐

66.Dentro del ultimo año te has sentido mal despues de haber fumigado? 1. Si ☐ 2. No ☐

67.Si es si, que has sentido, despues de haber fumigado (puede seleccionar varias respuestas)

1. Ganas de vomitar ☐ 2. Dolor de cabeza ☐

3. Vista turbia ☐ 4. Temblando los manos ☐

5. Mareos ☐ 6. Difilcutad respiratoria ☐

☐ ☐

7. Salivación ☐ 8. Cansancio ☐

9. Piel irritada ☐ 10. Falta de concentración ☐

11. Debilidad muscular ☐ 12. Otros, cuales ☐

68.Cuantas veces durante el ultimo año has sentido algunos de estos sintomas despues de haber fumigado?.....................................

69.Que plaguicidas has usado antes de sentir estos sintomas?...

70.Que tiempo duran los efectos? 1. Horas ☐ 2. Días ☐ 3. Semanas ☐

71.Que haces para curarte (puede seleccionar varias respuestas)?

1. Nada ☐ 2. Remedios caseros ☐ 3. Voy al centro de salud ☐

72.Cuantas veces te has sentido mal despues de haber mezclado o fumigado en toda tu vida?

73.Cuantas veces te has sentido mal despues de haber mezclado o fumigado durante el ultimo mes?................

74.Que plaguicidas has usado durante el ultimo més antes de sentir estos sintomas?

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75.Alguien en tu familia se ha sentido mal despues del contacto con plaguicidas?1.Si ☐ 2. N☐

76.Han habido intoxicaciones por plaguicidas aqui en la comunidad, dentro de los ultimos 5 años?

1. Si ☐ 2. No ☐

77.Porque se han intoxicado?Y Cuántos fueron

		Nro
1. accidental	☐	....
2. intento suicidio	☐	....
3. laboral	☐	....
4. Otros	☐	....

78.Cuando fue el ultimo caso?.........................

79.Han habido muertos por plaguicidas aqui en la comunidad, dentro de los ultimos 5 años?

1. Si ☐ 2. No ☐

80.Porque se han muerto?

		Nro
1. accidental	☐	....
2. intento suicidio	☐	....
3. laboral	☐	....

4. Otros ☐ ....

81.Cuando fue el ultimo caso?..

82.Hay diferencia en el efecto venenoso de los plaguicidas? 1. Si ☐ 2. No ☐

3. No se ☐

83.Cuales son los plaguicidas más fuertes que utilizas?

1 .... 2......................... 3. .... 4. ....5.......................

84.Cuales son los plaguicidas menos fuertes que utilizas?

1........................ 2..........................3...........................4. ....5.......................

85.Crees que los plaguicidas pueden tener efectos dañinos a tu familia?

1. Si ☐ 2. No ☐ 3. No se ☐

86.Si la anterior respuesta es si , indica que efectos?

____

87.Crees que los plaguicidas pueden tener efectos dañinos a tus animales?

1. Si ☐ 2. No ☐ 3. No se ☐

88.Si la anterior respuesta es si , indica que efectos

____

89.Crees que los plaguicidas pueden tener efectos dañinos al medio ambiente? (suelo, agua, aire)

1. Si ☐ 2. No ☐ 3. No se ☐

90.Si la anterior respuesta es si , indica que efectos

____

91.Aparte de fumigar los cultivos para que otra cosa utilizas los plaguicidas?

1. Fumigar mi casa ☐

2. Curar granos y semilla ☐

3. Uso en personas (parasitos, piojos) ☐

4. Otras actividades ☐

OBSERVACIONES

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Firma del Encuestador