Pesticides and Health in Highland Ecuadorian Potato Production: Assessing Impacts and Developing Responses

Article *in* International journal of occupational and environmental health · July 2002

DOI: 10.1179/oeh.2002.8.3.182 · Source: PubMed

5 authors, including:

Stephen Sherwood
Wageningen University

Charles Clinton Crissman

Victor Barrera
Instituto Nacional Autónomo de Investigaci…

Pesticides and Health in Highland Ecuadorian Potato Production:
Assessing Impacts and Developing Responses

DONALD C. COLE, MD, MSC, STEPHEN SHERWOOD, MPS, CHARLES CRISSMAN, PHD, VICTOR BARRERA, MSC, PATRICO ESPINOSA, MSC

Pesticide use in highland Ecuador is concentrated in the high-risk, commercial production of potatoes. Small farm families experience considerable exposure and adverse health consequences. The authors describe a three-pronged strategy to reduce health impacts: 1) a community-based process of education and provision of personal protective equipment to reduce exposure; 2) farmer field schools to increase agro–ecosystem understanding and to reduce pesticide use; and 3) policy interventions to restructure incentives and to reduce availability of highly toxic insecticides. They discuss the challenges faced by each and the ongoing need for integrated interventions both to reduce adverse pesticide health impacts in the developing world and to promote sustainability of agricultural production in highland ecosystems. *Key words*: pesticides; developing countries; environmental exposures; poisoning; nervous system disorders; agricultural workers' diseases; integrated pest management; prevention and control.

INT J OCCUP ENVIRON HEALTH 2002;8:182–190

Agriculture is an important industry (8.4% of GDP) in Ecuador, employing about a fourth of the economically active population.[1] All active ingredients of pesticides and most formulated pesticide products used in agriculture are imported. An initial rise in pesticide importation promoted by direct or indirect subsidies to pesticides gradually tapered off over the last two decades, but the value of pesticide imports has remained in the range of US$45–$50 million.[2] The United States is the largest supplier of pesticides to Ecuador, followed by a suite of European countries. Among the imports are a range of products whose use is more restricted in their countries of origin than in Ecuador, including those with World Health Organization toxicity ratings 1a and 1b.[3]

Potatoes are a traditional Andean crop, grown predominantly for internal or regional markets by tens of thousands of small to medium-sized potato producers in the highland Sierra region.[1] The National Agricultural Research Institute (INIAP) and the International Potato Center (CIP) have worked with local producers for many years, developing and implementing a variety of technologic innovations to improve productivity, particularly among poorer farmers. With a reorientation of agricultural research toward sustainable practices in the 1980s, both organizations became interested in examining the environmental and health impacts of current production methods. An approach to analyzing tradeoffs and synergies between production and health goals guided a program of research over the last decade.[4]

We note the pesticide use in potato production in one of the most productive regions of the Ecuadorean Sierra, the northern province of Carchi (see Figure 1). We describe pesticide exposure pathways uncovered, the health impacts of such exposures among the farm population, and tradeoffs between crop production goals and human health. Based on observational research, we devised interventions informed by an ecosystem approach to human health[5] with the aim of reducing exposure to and use of high-toxicity pesticides in a community-centered project called "Eco-Salud" (eco-health). We share some preliminary results, along with our concerns about their limitations. To confront some of the latter, we have engaged in activities to influence policy relative to pest-management approaches at provincial and national levels. We describe these efforts and conclude with some directions for further work.

PESTICIDES IN POTATO PRODUCTION

Since the 1960s, potato production in Carchi has increasingly relied on pesticides to control major pests and diseases. Among the most important pesticides are: dithiocarbamate–metal fungicides, particularly man-

Received from the International Potato Center (CIP), Quito, Ecuador. Presented in part during Ecohealth lectureship by Dr. Cole, February 2001, and presentations at national meeting on the Impact of Pesticides on Potato Production, Health and the Environment, Quito, Ecuador, May 31, 2001. Supported by the International Development Research Centre, EcoHealth grant to CIP Project #004321/98-0011-01, United States Agency for International Development IPM-CRSP project, and the Food and Agriculture Organization's Global IPM Facility.

Address correspondence and reprint requests to: Donald C. Cole, MD, Department of Public Health Sciences, Faculty of Medicine, 4th Floor McMurrich Building, 12 Queen's Park Crescent W., University of Toronto, Toronto, ON, Canada M5S 1A8.

cozeb, for control of disease in the damp, cool climate of the highlands; organophosphorus insecticides, particularly methamidophos and profenophos, to control foliar insects; and carbamate insecticides, particularly carbofuran, to control the Andean weevil.[4,6] On average, farmers make seven applications with three products per application to each cycle of potatoes, with product and application costs combined accounting for about a fourth of all potato-production costs among the small and medium-sized producers in the region. Using current production technology, pesticides on average contribute to substantial returns, although losses are also common due to considerable variation in farm management styles and volatile prices in the local and regional potato markets, which extend to Colombia and Peru.

Based on survey, observational, and interview data, the vast majority of pesticides are bought based on their commercial names, with only a small minority of farmers reporting receiving information about pesticide hazards and safe practices from the vendors.[7] Pesticide storage is usually relatively brief (days to weeks) but occurs close to farmhouses because of fear of robbery. Farmers usually mix the pesticides in large barrels, without gloves, resulting in considerable dermal exposure.[8] Farmers and, on larger farms, day laborers apply pesticides using backpack sprayers on hilly terrain. Few use personal protective equipment, for a variety of reasons, including social pressure (e.g., masculinity is tied to the ability to withstand pesticide intoxications), limitations of quality and availability, and the high cost of the equipment. A recent study found that during pesticide applications most farmers wet their skin, in particular the skin of the back (73% of respondents) and hands (87%).[7] Field exposure trials using patch monitoring techniques showed that during foliar applications on mature crops, considerable dermal deposition occurred on the legs.[4] Other studies have shown that additional exposure occurs in the field during snack and meal breaks, when limited hand washing is the norm.

Excess mixed product may be applied to other tuber crops, thrown away with containers in the field, or spread out around the farmhouse. Clothing worn during application is often stored and used repeatedly before washing. Usually contaminated clothing is washed in the same area as family clothing, though in a separate wash. The extent of personal wash up varies, but is usually insufficient to remove all product from both the hands of the applicator and the equipment. Separate locked storage facilities for application equipment and clothing are uncommon. Swab methods have found pesticide residues on a variety of household surfaces and farm family clothing.[8]

Family members are thus exposed to pesticides in their households and in their work via a multitude of contamination pathways. Such contamination results in

Figure 1—Potato-producing province of Carchi, Ecuador (location of Carchi indicated by arrow).

Latitude = 0.5°N; altitude = 2,700–4,200 m; mean temperature = 12°C; mean precipitation = 1,000 mm; growing season year-round.

considerable health impacts that range from subclinical neurotoxicity,[9,10] through poisonings with and without treatment,[11] to hospitalizations and deaths.[12] A pyramid of estimated impacts, similar to that described[13] over a decade ago, can be devised from our research (Figure 2).

DECREASING EXPOSURE

Seeking to engage communities in a participatory learning–action process, we started by informing members of three rural communities of pesticide safety concerns, in particular the results of our earlier studies of exposure and health impacts. To better determine pesticide exposure pathways, we used fluorescent tracer methods[14] with volunteer participants in each commu-

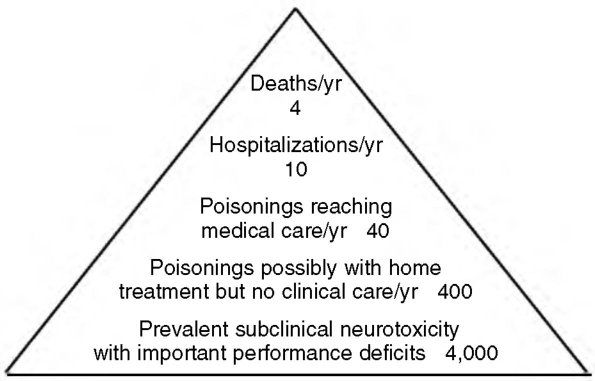

Figure 2—Pyramid of estimated pesticide health impacts (numbers/10,000 rural population).

Pesticide mixing and pouring into backpack sprayer beside a stream

nity. During presentations in community meetings, the discovery of tracer on applicators' hands and faces, children's faces, and household objects such as the kitchen table generally stunned people.[15] Footage of the tracer studies has appeared on national television, and a media specialist is producing a training video that will include participant comments and recommendations for reducing exposure.

In community meetings with women, considerable discussion of the health effects of pesticides, the importance of hygienic practices, and the treatment of poisonings has taken place. Farm families' dependence on pesticides using current production methods generates considerable tensions among spouses. In fact, farmers often interchangeably use the terms *el remedio* (literally, the treatment) and *el veneno* (the poison) to signify pesticides. On one hand, the need to buy food and pay for their children's schooling when work options are limited leads to an acceptance of the seemingly less important risks of pesticides. Such priority is galvanized by a common perception associating capacity to withstand pesticide intoxications with inner strength and *machismo*. As one community informant recounted:

> One time, my sister Nancy came home very pale and said that she thought she had been poisoned. I remember that the pesticide company agricultural engineers had spoken about this, so I washed her with lots of soap on her back, arms, and face. She said she felt dizzy, so I helped her vomit. After this she became more resistant to pesticides and now she can even apply pesticides with our father.

On the other hand, many women are particularly concerned about health impacts that may lead to poisoning of their children and to chronic ill health for them and their spouses, ultimately jeopardizing the economic and social stability of the family. Such dual vulnerability has been demonstrated in community meetings with hard words between spouses about men's practices that result in personal and household exposures.

In response, the farmers requested that Eco-Salud facilitate provision of high-quality personal protective equipment (PPE), unavailable at the dozens of local agrochemical distributors. Eco-Salud staff found high-quality PPE (mask, gloves, overalls, and pants) through health and safety companies in the capital. The project also agreed to a no-interest, two-month credit towards the purchase price. Forty-six participating families in three communities (over two thirds) purchased PPE costing $34/set, the equivalent of over a week's wages at the going rate. Some farmers are renting their equipment to others in the community in order to recover the costs.

In addition, Eco-Salud staff visited homes to discuss with individual families pesticide safety strategies, in particular improved storage of pesticides and PPE, use of a low-volume and constant-pressure nozzle that provides better coverage with less pesticide, and more consistent hygienic practices.

Yet limitations of the "safe use of pesticides" (SUP) approach are apparent. As a letter to the Eco-Salud project from the Ecuadorean pesticide industry association (APCSA) notes, an important assumption of SUP is that exposure occurs because of "a lack of consciousness in the safe use and handling of these products [pesticides]." Although in our survey in Carchi, a low percentage of women in farm families (14%) had received any training in the use of pesticides, over 80% of male farmers had received some training regarding precautions to be taken when using pesticides. As well, labels are supposed to be an important part of the hazard-communication process. Yet our work in Carchi indicates that farm members often cannot decipher the industry's warnings and instructions on most pesticide labels. Although 87% of the population in our project area is functionally literate, over 90% could not explain the meaning of the colored bands on pesticide containers indicating pesticide toxicity. Rather, most believed that toxicity was best ascertained through product odor. This led farmers to identify less toxic compounds, such as profenos, as highly toxic. Tragically, companies introduce odors to products for marketing reasons, so there is no necessary association between smell and toxicity. Hence even the agrochemical industry's universal, seemingly simple system of toxicity warning and handling recommendations has not entered the local knowledge system.

On diverse occasions, the national pesticide association has implied that farmers are responsible for the results of their mishandling of products. Not only is this position inconsistent with international legal standards (as evidenced by recent litigation between the U.S. government and the tobacco industry), it also demonstrates unawareness of the complexity of the pesticide problem, an ignorance that underlies the general conceptualization of SUP. SUP's focus on isolation of pesticides and PPE is misguided. Isolation is particularly difficult in open environments such as field agriculture, where farming infrastructure and housing are intimately related and some contamination of the household is virtually inevitable, particularly in poorer households. Farmers regard PPE as uncomfortable and "suffocating" in humid warm weather, leading to the classic problem of noncompliance associated with individually oriented exposure-reduction approaches.[16] Examination of all components of the classic industrial hygiene hierarchy of controls[17] would suggest the need for additional elements in a harm-reduction program. Effectiveness of the measures can be ranked from the most effective (1) to the least effective (7):

1. Eliminate more highly toxic compounds, e.g., carbofuran and methamidophos
2. Substitute less toxic, equally effective alternatives
3. Reduce use through improved equipment, e.g., low-volume spray nozzles
4. Isolate people from the hazard, e.g., with locked separate pesticide storage
5. Label products and train applicators in safe handling
6. Promote use of personal protective equipment
7. Institute administrative controls, e.g., rotating applicators

Administrative controls are not readily applicable among smallholder farmers, leaving SUP to focus on elements 3 to 6. Unfortunately, one recent seven-year study by Novartis, now Sygenta and formerly Ceiby-Geigy and one of the largest pesticide producers in the world, found that SUP interventions in Latin America, Africa, and Asia were expensive and largely ineffective, particularly among smallholders.[18] The authors argue that: "The economics of using pesticides appeared to be more important [to small farmers] than the possible health risks" (p. 121). The most toxic compounds remain among the cheapest on the market in Carchi, partly due to restricted markets in most industrial countries. The need to devise economically viable alternative production methods to forward implementation of elements 1 and 2 led us to activities to decrease pesticide use in potato production.

Pesticide mixing and pouring without gloves and respiratory protection


Pesticide application in a potato field; the white patches on the worker's clothing are for exposure monitoring

DECREASING USE

The National Autonomous Agricultural Research Institute (INIAP) field office in Carchi has had considerable experience in using participatory methods for applied research, such as for the development of late-blight-disease–resistant potato varieties. They built on relationships with Carchi communities to implement farmer field schools (FFSs), a method borrowed from the Food and Agriculture Organization's experience in Southeast Asia and Africa and recently introduced for adaptation to the Andes.[19] The FFS is based on farmer participatory environmental education and purposefully seeks to change the paradigm of IPM, which often centers on simple rules such as "economic thresholds" and transfer of single-element technologies within a framework of ongoing use of pesticides.[20] In contrast, FFS programs prioritize group learning and organization for the implementation of knowledge and management-intensive alternatives to pesticides, such as biologic control, insect traps, good agronomy, and other means to crop health. As one graduate of FFS in Carchi noted:

> When we talk about the insects [in the FFS] we learn that with the pesticides we kill everything, and I always

Neurobehavioral testing of a pesticide-exposed worker

> make a joke about inviting all the good insects to come out of the field before we apply pesticides. Of course, it is a poison, and we kill everything. We destroy nature when we do not have another option for producing potato.

In practice, the FFS has broadened goals beyond common understanding of integrated pest management (IPM) to a more holistic approach of promoting plant and soil health. The FFS method adapts to the diverse practical crop needs of the farmers, be they soil preparation, production, storage, commercialization, or others. The FFS aspires to develop the innovative capacity of farmers, as exemplified by how a graduate has improved on insect traps tested in his FFS:

> I always put out the traps for the Andean weevil, even if I plant 100 quintals, because it decreases the number of adults. It is advantageous because we do not need to buy much of that "venom" Furadan [a carbamate insecticide]. But I do use them differently. After ploughing, I transplant live potato plants from another field, then I do not need to change the dead plants every eight days.

In an iterative fashion, FFS participants conduct experiments on comparative (conventional vs IPM) small plots (about 2,500 m^2) to identify opportunities for improving production and achieving greater IPM. After two seasons, initial evaluation results in three communities were impressive. Through the use of alternative technologies, such as Andean weevil traps, late-blight–resistant potato varieties, specific and low-toxicity pesticides, and careful monitoring of the ecology (e.g., beneficial insects as well as pests) before spraying, farmers were able to decrease pesticide sprayings from 12 in conventional plots to seven in IPM plots while maintaining or increasing production.[21] The amount of active ingredient of fungicide applied for late blight (*Phytophtera infestans*) decreased by 50%, while insecticides used for the Andean weevil (*Prenmotrypes vorax*) and leafminer fly (*Liriomysa quadrata*), which had commonly received highly toxic carbofuran and methamidophos applications, decreased by 75% and 40%, respectively. Average yields for both conventional and IPM plots were about 19 t/ha, and overall productivity, after accounting for labor demands, increased by 37%. FFS participants have identified how to maintain the same level of potato production with half the outlays in pesticides and fertilizers, decreasing production costs from about $US 104 to $US 80 per ton. Because of the number of farmers involved in FFS, it was difficult to accurately include labor in the cost–benefit analysis. Nevertheless, the farmers felt that the increased time for scouting and using certain alternative technologies, such as the insect traps, would be compensated for by decreased pesticide applications, not to mention decreased medical care visits. Complementary projects have supported follow-up activities, including the production of a manual on facilitator training,[22] the training of 27 FFS facilitators, the transition of FFSs to small-enterprise production groups, and the establishment of a farmer-to-farmer extension program.

Yet we have encountered limitations to the FFS approach that argues for diverse strategies. Farmers differ in their levels of resources, their willingness to take risks, and their incentives to change production methods.[23] Paredes classified farmers by their approaches to farming and found FFSs were more attractive to certain social groupings than to others. In particular, the most enthusiastic participants were "landless laborers" whose participation was most motivated by the opportunity to co-invest in production and by the platform for horizontal social relationships, and "highly pragmatic" and "inquisitive" farmers who had a natural interest in the discovery learning. Meanwhile, field schools appeared to be of less interest to "high-risk takers," those individuals who regularly overextended their resources in agriculture and were readily open to adopt (and disadopt) technologies, as well as "intermediate farmers," who tended to co-invest in land, rather

A roadside advertisement for methamidophos on the side of a house than directly invest their financial resources in production. Paredes concluded that FFSs, while certainly positive for certain social groups, were not reaching broader populations in the community and, if not managed properly, could contribute to social divisions. The need arises for a variety of interventions that target the interests of particular social groups in ways that contribute to greater social cohesion at the community level.

Farmer field schools enable farmers to more critically assess the advice of pesticide salesmen. As one FFS graduate said:

> Prior to the field school coming here, we used to go to the pesticide shops to ask what we should apply for a problem. Then the shopkeepers wanted to sell us the pesticides that they could not sell to others, and they even changed the expiry date of the old products. Now we know what we need, and we do not accept what the shopkeepers want to give us.

Yet farmers are still influenced by the chemical bias of "modern agriculture." As Campbell[24] has contended, "One of the problems with [biologically-centered] systems of controls is that there is usually no patentable or marketable product, and there is no commercial interest and few research funds." Market culture pervades small agricultural communities. "Modernization" policies and structural adjustments over the last decade have dismembered public agricultural extension and research services that over the years had improved farmers', extension agents', and researchers' knowledge of changing pests and conditions. Such knowledge of environment–pest interactions is essential for the development of localized technology development and farmer/community decision-making capacity. Such investments are essential to enable communities to deal with fluctuating markets for both inputs and agricultural produce and to confront external pressures generated by "modernization" initiatives that threaten community livelihood.[25]

INFLUENCING POLICY

Tackling the broader context of pesticide use in agriculture requires involvement of many stakeholders. To this end, we have been instrumental in a series of initiatives to make our research results more widely known, engage in discussion of policy options, and generate actions to reduce pesticide impacts.

A series of short radio programs was developed to air throughout the province. Eco-Salud staff linked with other institutions during their priority-setting meetings. For example, the project nurse participated in cantonal Health Council meetings and the project educator joined a local development consortium centered in one community. In addition, project staff met with local and provincial political officials.

Common liquid carbofuran (90%) formulations imported from Colombia

Such initial work led to a province-wide stakeholders' meeting entitled "The Impacts of Pesticides on Health, Production, and the Environment" in October 1999. One hundred and five representatives from government, industry, development organizations, communities, and the media participated. Presidents from the provincial boards of agriculture and health chaired sessions. Ministerial representatives from agriculture, health, and education participated, as well as the governor and mayors or representatives from all of the provincial municipalities. After a morning of sharing research results, participants broke into four discussion groups in order to assess opinions on the situation, to determine suggestions for particular stakeholders (farmers, government, industry, and consumers), and to make recommendations for future action. As one consequence of the meeting, the group formed a small committee composed of the directors from INIAP, the Ministry of Education, and the Ministry of Health, who drafted a "Declaration for Life, Environment and Production in Carchi." The Declaration included the following demands:

Farmer field school workers identifying pests

Class on pest life cycle

- Assure greater control on the part of the Ecuadorian Agricultural Health Service (SESA) of the formulation, sale, and use of agrochemicals, including the prohibition of highly toxic products (WHO categories 1a and 1b)
- Introduce to the basic education curriculum content on the impacts of pesticides on health, the environment, and farming productivity
- Include integrated pest management as part of degree requirements for university-level agricultural technical training
- Commit further resources to research and training in integrated crop management with an orientation towards the reduction of pesticide use and safe use of pesticides.
- Promote in rural communities the raising of awareness of the collateral impacts of agricultural practices and the use of more environmental and health-friendly practices.
- Demand the direct financial support of the agrochemical industry in the completion of these resolutions.

Teaching pest identification in a farmer field school

The first recommendation resonated soundly with earlier-cited research on SUP that concluded ". . . any pesticide manufacturer that cannot guarantee the safe handling and use of its toxicity class 1a and 1b products should withdraw those products from the market."[18] The next four involve education and research initiatives on the part of various stakeholders to gradually shift agricultural production to more sustainable practices. The final recommendation is in keeping with a long-standing proposal for post-marketing surveillance, similar to that which is carried out on drugs, funded by agrochemical producers.[26]

Although the impact of the declaration may be difficult to assess, it has guided subsequent institutional actions in the province. Further, a petition was circulated and presented at a corresponding national multistakeholder meeting held in May 2001, organized by the national Technical Committee on Pesticides, an inter-ministry committee of the government and private industry. The Committee built on the Carchi declaration to develop a national action plan that amplified the scope to the national level. Unfortunately, prior to the national meeting, pressure from national and international pesticide industry representatives persuaded government officials to withdraw support for the reduction and eventual elimination of highly and extremely toxic pesticides. Nevertheless, agricultural development organizations expressed considerable interest in Carchi farmers' presentation of IPM methods. Health ministry officials and Pan American Health Organization representatives indicated intentions to play a more active training, monitoring, and advocacy role, similar to that of the PlagSalud project in Central America.[27]

Ultimately, as Murray and Taylor[16] have said, "It should be apparent that the pesticide problem cannot be solved without the active participation of the pesticide industry." While at times including a powerful partner such as the pesticide industry arguably has interrupted political progress, media attention and public opinion have helped to level the playing field. In this way, the research results have played an important mediation role. Multistakeholder interactions have led to new opportunities. The industry has begun to accept that the pesticide problem in Carchi is not simply one of limited information and attitude, but rather one more deeply and complexly rooted in social issues.

TABLE 1. Examples of Interventions by Level of Society and Players

Level	Players	Example
field	farmers and trainers	• farmer field schools (FFS) on alternative ways of potato production including pest identification, monitoring and trapping
farm household	couples, older children and women's group facilitator	• discussion groups on health risks of pesticides, ways of prioritizing child and family health in household decision-making
community	mayors, school teachers, cooperative leaders, labourers	• introduction to curriculum of material on pesticide health risks and integrated pest management • organization of day labourers to demand compliance with health and safety law requiring provision of personal protective equipment
province	cantonal health councils, development coordinating bodies	• setting pesticide poisonings as a priority for the public health system • provincial declaration on pesticides
country	government ministries, non-governmental development organizations (NGO), pesticide importers and distributors, researchers	• technical committee action plan • funding and development of FFS and farmer based research networks to revive traditional agricultural methods and share experience with integrated pest/crop management (IP/CM)
international	international crop protection associations, international NGOs, international health (WHO) and agriculture (FAO) organizations, researchers	• promote phasing out of use of WHO category I insecticides • promote stronger markets for personal protective equipment • support research and training in IP/CM approaches

LAPCA's and APCSA's commitment to fund independently-led interventions appears to be a very positive step to enabling local actors to design and implement more effective strategies.

DIRECTIONS

We have outlined a broad range of strategies at different levels of society to reduce the health impacts of pesticides and move towards more sustainable potato production (Table 1).[28] Underlying such strategies is an understanding that win–win conditions are possible, as tradeoff econometric models exemplify,[29] that change is a socially complex process, and that involvement in and evaluation of such changes are important roles for occupational and environmental health practitioner/researchers. Our approach is consistent with that of the Asian IPM programs and means that, in addition to other considerations, IPM demands *empowerment*.[30] A leading agricultural systems researcher, Niels Röling, has argued that our very existence increasingly depends on greater ecosystem consciousness and management, which will require greater equity and emancipation of traditionally disfavored sectors.[31] Clearly, issues of differential power and knowledge between different stakeholders will have to be confronted[32,33] if societal and agro–ecosystem changes are to be moved in more sustainable directions to ultimately promote human health.

The authors acknowledge the research and intervention contributions of the INIAP and Eco-Salud team in Carchi, in particular the efforts of Lilian Basantes, Mariana Pérez, Myriam Paredes, Jovanny Suquillo, Luis Escudero, and Fernando Chamorro.

References

1. Herrera M, Carpio H, Chávez G. Estudio Sobre el Subsector de la Papa en el Ecuador. INIAP (Instituto Nacional de Investigación Agro-Pecuaria), Programa Nacional de Raices y Tubérculos. Quito, Ecuador, 1999, 140 pp.
2. Lee DR, Espinosa P. Economic reforms and changing pesticide policies in Ecuador and Colombia. In: Crissman CC, Antle J, Capalbo S (eds). Economic, Environmental and Health Tradeoffs in Agriculture: Pesticides and the Sustainability of Andean Potato Production. Lima Peru: CIP (International Potato Center) and Dordrecht/Boston/London: Kluwer Academic Publishers, Natural Resource Management and Policy Series, 1998, 120-42.
3. International Program on Chemical Safety. The WHO recommended classification of pesticides by hazard and guidelines to classification 1992–1993. Geneva, Switzerland: United Nations Environment Program, International Labor Organization, World Health Organization; 1992 (WHO/IPCS/92.14).
4. Crissman CC, Antle J, Capalbo S (eds). Economic, Environmental and Health Tradeoffs in Agriculture: Pesticides and the Sustainability of Andean Potato Production. Lima Peru: CIP (International Potato Center) and Dordrecht/Boston/London: Kluwer Academic Publishers, Natural Resource Management and Policy Series, 1998, 281 pp.
5. Forget G, Lebel J. An ecosystem approach to human health. Int J Occup Environ Health. 2001;7(2):S1-S38.
6. Barrera VH, Norton G, Ortiz O. Manejo de las principales plagas y enfermedades de la papa porlos agricultores en la provincia del Carchi, Ecuador. Quito, Ecuador: INIAP (National Agricultural Research Institute), 1998: 65 pp.
7. Espinosa P, Crissman C, Mera-Orcés V, Paredes M, Basantes L, Escudero L. Conocimientos, actitudes y practicas de manejo de

plaguicidas por familias productoras de papa en Carchi. Chapter 3 in Crissman CC, Espinosa P (eds). Las Plaguicidas. Impacto en la producción, salud y medio ambiente en Carchi. Un compendio de investigaciones y respuestas multidisciplinarias. Quito, Equador: Editorial Abya-Yala. 2002, in press.

8. Merino R, Cole DC, Presencia de plaguicidas en el trabajo y el hogar. Chapter 5 in Crissman CC, Espinoca P (eds). Las Plaguicidas. Impacto en la producción, salud y medio ambiente en Carchi. Un compendio de investigaciones y respuestas multidisciplinarias. Quito, Equador: Editorial Abya-Yala. 2002, in press.
9. Cole DC, Carpio F, Julian J, Leon N, Carbotte R, De Almeida H. Neurobehavioural outcomes among farm and non-farm rural Ecuadorians. Neurotoxicol Teratol. 1997;19:277-86.
10. Cole DC, Carpio F, Jullian J, León N. Assessment of peripheral nerve function in an Ecuadorean rural population exposed to pesticides. J Toxicol Environm Health. 1998;55:77-91.
11. Crissman C, Cole DC, Carpio F. Pesticide use and farm worker health in Ecuadorian potato production. Am J Agric Econ. 1994;76:593-7.
12. Cole DC, Carpio F, León N. Economic burden of illness from pesticide poisonings in highland Ecuador. Pan Am Rev Public Health. 2000;8:196-201.
13. Jeyaratnam J. Acute pesticide poisoning: a major global health problem. World Health Stat Q. 1990;43:139-44.
14. Fenske R, Wong S, Leffingwell J, Spear R. A video imaging technique for assessing dermal exposure. II. Fluorescent tracer testing. Am Ind Hyg Assoc J. 1986;47:771-5.
15. Harari R, Albuja G. Informe de Trabajo para el Centro Internacional de la Papa (CIP) sobre el Uso del trazador Fluorescente para identificar expositión a plaguicidas en la producción de papas en el Carchi. Quito, Ecuador: IFA, 2000.
16. Murray DL, Taylor PL. Claim no easy victories: evaluating the pesticide industry's global safe use campaign. World Development. 2000;28:1735-49.
17. Plog BA. Fundamentals of Industrial Hygiene. 4th ed. Ithaca, NY: National Safety Council, 1996.
18. Atkin J, Lesinger KM (eds). Safe and Effective Use of Crop Protection Products in Developing Countries. London, UK: CABI Publishing, 2000: 163 pp.
19. Sherwood S, Nelson R, Thiele G, Ortiz O. Farmer field schools in potato: a new platform for participatory training and research in the Andes. Institute for Low External Input Agriculture (ILEIA). 2000;16(4):24-5.
20. Gallagher KD. Community study programs for integrated production and pest management: farmer field schools. In: FAO, Human Resources in Agricultural and Rural Development, Rome, Italy, 2000: 60-7.
21. Barrera V, Escudero L, Suquillo J, Sherwood S, Norton G. Validación y difusión de modelos de manejo integrado de plagas y enfermedades en el cultivo de papa: Una experiencia de capacitación participativa en la provincia de Carchi, Ecuador. Special Report for the USAID IPM/CRSP Project, 2001: 15 pp.
22. Pumisacho M, Sherwood S (eds). Herramientos de Aprendizaje para Facilitadores. Manejo Integrado del Cultivo de Papa. Quito, Ecuador: INIAP and CIP, 2000: 181 pp.
23. Paredes M. We are like the fingers of the same hand: peasants' heterogeneity at the interface with technology and project intervention in Carchi, Ecuador. MSc thesis, Wageningen, The Netherlands: Wageningen University, 2001: 150 pp.
24. Campbell R. Biological control of soil-borne diseases: some present problems and different approaches. Crop Protection. 1994;13(1):4-13.
25. Sherwood S, Larrea S. Looking back to see ahead: farmer lessons and recommendations after 15 years of innovation and leadership in Güinope, Honduras. Agriculture and Human Values. 2001;18:195-208.
26. Loevinsohn ME. Improving pesticide regulation in the third world: the role of an independent hazard auditor. In: Forget G, Goodman T, de Villiers A. Impact of Pesticide Use on Health in Developing Countries: proceedings of a symposium held in Ottawa, ON, Canada, 17–20 September 1990. Ottawa, ON, Canada: IDRC, 1993: 166-7.
27. Keifer M, Murray DI, Amador R, et al. Solving pesticide problems in Latin America: a model for health-sector empowerment. New Solutions. 1997;7(2):26-31.
28. Sherwood S, Cole DC, Paredes M. Estrategias de intervención para reducir los riesgos cuasados por plaguicidas en al Carchi. In: Crissman, Espinosa P (eds). Centro Internacional de la Papa. Las Plaguicidas. Impacto en la producción, salud y medio ambiente en Carchi. Un compendio de investigaciones y respuestas multidisciplinarias. Quito, Equador: Editorial Abya-Yala. 2002, in press.
29. Angle JM, Cole DC, Crissman CC. Further evidence on pesticides, productivity and farmer health: potato production in Ecuador. Agricultural Econ. 1998;18:199-207.
30. Matteson PC, Gallagher KD, Kenmore PE. Extension of integrated pest management for planthoppers. In Denno RF, Perfect TJ (eds). Asian Irrigated Rice: Empowering the User. London, U.K.: Chapman and Hall, 1994: 656-87.
31. Röling NG, Wagemakers MAE (eds). Social learning for sustainable agriculture. Cambridge, New York, Melbourne: Cambridge University Press, 1998.
32. Watterson A. Agricultural science and food policy for consumers and workers: recipes for public health successes or disasters? New Solutions. 2000;10:317-24.
33. London L, Rother HA. People, pesticides and the environment: who bears the brunt of backward policy in South Africa? New Solutions. 2000;10:339-50.