INFANT ENVIRONMENTAL HEALTH PROGRAM USING AN ECOSYSTEM APPROACH (ISA)

Project: A holistic analysis of the sustainability of banana and plantain production systems regarding pesticide exposure and its effect on neurodevelopment in early life

FINAL TECHNICAL REPORT

EXECUTIVE SUMMARY

Project number IDRC: 105296-001

Written by: Berna van Wendel de Joode, Rosario Quesada

Period covered by the report: April 2009 - April 2013
Date of presentation: May 2013

Country / Region: Latin America and the Caribbean

Central American Institute for Studies on Toxic Substances (IRET), Universidad Nacional (UNA), Heredia, Costa Rica.

Foto: Camilo Cano

CONTEXT, VISION, MISSION, STRATEGIC OBJECTIVES AND EXPECTED RESULTS OF INFANT AND ENVIRONMENTAL HEALTH (ISA)

The project "A holistic analysis of the sustainability of banana and plantain production systems regarding pesticide exposure and its effect on neurodevelopment in early life" also called Infant and Environmental Health *'Infantes y Salud Ambiental (ISA)'* Program was created to assess and improve the sustainability of production systems of banana and plantain, using ecosystem approaches to human health, particularly with regard to pesticide exposure and neurodevelopment of 0-2 years-old babies. This, because populations living nearby banana plantations are likely to be continuously exposed to pesticides (Barraza et al., 2011; van Wendel de Joode et al., 2012).

Pesticides are one of the main environmental problems, not only in Costa Rica but also in many other developing countries. Worldwide, Costa Rica is the second largest banana exporter, after Ecuador (Corbana, 2013). In Costa Rica, large-scale banana growing depends on intensive pesticide use; more than 2 millions of kilograms of pesticides are applied annually on 40 thousand hectares of land (Bravo et al. 2012; CORBANA 2013). Its use includes weekly aerial applications of fungicides (Barraza et al., 2011) and three to four-monthly ground applications of highly toxic nematicides, and continuous use of insecticide-treated bags to protect the fruits (van Wendel de Joode et al., 2012). In Costa Rica, 99% of banana produced for export is grown in Limon province, as well as most of the plantain production (Sanchez and Zuñiga, 2004). In indigenous communities where plantains are being produced by smallholders, highly toxic pesticides are increasingly being used (Polidoro et al., 2008; Fieten et al., 2009).

Moreover, little is known about positions of stakeholders with regard to proposals for risk reduction. In addition, conventional studies do not relate the analysis of pesticide risk perceptions in view of labor processes, production strategies, coping strategies, gender, access to resources, and actions of state agencies in areas of health, agriculture and environment.

During the last decade the conventional farming model with high chemical inputs has become examined worldwide, both in developed and developing countries. Research on alternatives to pesticide use is a relatively new, and increasingly important, area in agricultural sciences. Alternative methods of pest control are crop- and environment- specific. Therefore, the development of alternative methods is an ongoing challenge, and subject to change (Altieri, 1997; Arauz, 1998; Chaverri, 2002).

The above described context of health, social and economic factors led the ISA-team to consider the vision, mission and strategic objectives described below.

VISION

"Inhabitants of the '*Huetar Atlántica'* region have a better quality of life, in particular children, and are less exposed to environmental health risks associated with pesticide use.''

MISSION

"To improve health of people living in the '*Huetar Atlántica'* region by analyzing impact of pesticides on children and promote implementation of alternatives to pesticides, within its social context, in a participatory manner, respecting environmental principals and issues of gender and equity.''

OBJECTIVES

GENERAL

To evaluate and improve sustainability of banana and plantain production systems using an ecosystem health approach, with special attention to pesticide exposure and neurodevelopment in early life.

SPECIFIC

1. To understand the socio-economic and ecological context of current banana and plantain production systems, how this context relates to pesticide use and exposure, and how risks and risk reduction strategies are perceived by different stakeholders;

2. To gain knowledge about pesticide exposure pathways and levels in pregnant women who are part of banana and plantain production systems, and understand how prenatal pesticide exposures affect health conditions and neurodevelopment of their newborn children;

3. To achieve a reduction of pesticide use and exposure in communities with different types of banana and plantain production systems by piloting different risk reduction activities and strengthening local and national capacity among community people, researchers and other stakeholders to ensure that collective knowledge and activities of risk reduction produce appropriate policy impact;

4. To strengthen ecohealth research capacity in Costa Rica in the context of an international collaborative research group.

MAIN SCIENTIFIC RESULTS

OBJECTIVE 1: UNDERSTAND SOCIO-ECONOMIC AND ECOLOGICAL CONTEXT OF CURRENT BANANA AND PLANTAIN PRODUCTION SYSTEMS

The analysis of pesticide risk perceptions was deepened and extended. In Talamanca, Matina and Siquirres we put a lot of effort to better understand risk perception of different social actors have with respect to pesticides.

In Talamanca The study on "The use of pesticides in banana and plantain production and risk perception among local actors in Talamanca" (Barraza et al, 2011) indicates that:

a) In Talamanca large-scale banana and plantain farming are perceived as one of the major problems because of its dependence of pesticides; b) Plantain farmers have adopted use of highly toxic pesticides with a similar pattern of use as large-scale banana plantations, but in conditions of extreme poverty; c) Economic considerations were mentioned as principal underlying reason for pesticide use: producers need to meet production standards, both quantity and quality, and on the other hand, economical agents such as intermediaries pressure smallholders to use certain pesticides, by paying less for cosmetically less attractive plantains; d) Aerial spraying on banana plantation was considered by most stakeholders as an important determinant of exposure for the population living near these plantations; e) In general indigenous banana producers and plantation workers had general knowledge of pesticides, but knew little about acute health effects, and almost nothing about exposure routes and pathways, and chronic effects; f) Risk perceptions were modulated by factors such as position of persons in the production process and gender.

The study by Barraza et al. (2013) 'Social movements and risk perception: unions, churches, pesticides and bananas in Costa Rica', has generated considerable knowledge about: a) **Scientific pesticide risk analysis is not the only force that shapes emerging societal perceptions of pesticide risks. Social movements influence the priority given to particular risks and can be crucial in putting health and environmental risk issues on the political and research agend**a; b) Foro Emaús developed activism around pesticide issues and put pressure on governmental agencies and banana companies and shaped people's perception of pesticide risks; c) The success of the Foro Emaús movement led to the reinforcement of a counteracting social movement (Solidarismo) by conservative sectors of the Catholic Church and the banana companies. We found that the participation of unions in Foro Emaús is an early example of social movement unionism.

We made a social and economic characterization of communities in the cantons of Talamanca (Carranza 2012, Wentink 2012), this characterization confirms the findings of Barraza et al. (2011) that "economic considerations are the main reason for plantain producers to use the insecticide-treated bags." In the indigenous territories there is a monopoly of intermediaries in plantain trade, who pay lower prices, usually half, for non-bagged plantain. The only type of bag that is being sold in pesticide-stores is chlorpyrifos-treated bags. Persons who are actually in contact with the bags, usually contract workers, feel obliged to accept this kind of work as jobs are scarce. The results of interviews about possibilities to use alternatives to chlorpyrifos-treated bags of Wentink (2012) indicate that **economic uncertainty makes producers critical about possible**

alternatives. They show, however, as well interest in learning about alternatives, and try alternatives themselves.

Carranza (2012) found that in the Bribri-Cabécar indigenous territories 268000 bags are used monthly, corresponding to 5.900 kilograms (kg) of insecticide- treated plastic per month , of which only 1.700 kg are being collected. Besides the problem of pesticide contamination because of this bag use, there is also an issue of environmental pollution with plastics.

Activities associated with this goal have increased understanding how socioeconomic and ecological context relates to use of, and exposure to pesticides. This is illustrated as well by results of work performed with community stakeholders:

In Matina County, we extended community outreach activities work in the village called '4 Millas' through a participatory course for community leaders on EcoHealth developed by the Community of Practice on Ecosystem Health Approaches in Latin American and the Caribbean (CoPEH-LAC; www.una.ac.cr/copehlac). We integrated into this course fieldwork of the thesis "Evaluation of the quality of water for human consumption and proposal aimed at its improvement in the community '4-Millas' Matina, Limón". Both activities allowed us to increase our knowledge on reality, history and problems of this community.

Data from the environmental study performed as part of activities related to objective 2, prove that environmental air of this community is contaminated with multiple pesticides, used at surrounding banana plantations. Community leaders, members of the Development Association, Sports Committee, Emergency Committee, Church, participated in the course on Ecohealth, through which we achieved a participatory collaboration.

The work with Community Water Boards (ASADAS for its acronym in Spanish), has enabled the project researchers to learn about organization of community groups in Matina, allowing us to learn about behaviours and knowledge that community members have with respect to pesticides and to plan dissemination activities. Community leaders have used information supplied by the ISA project in their struggle to have access to drinking water of better quality, a process that is being accompanied by the project researchers.

The work we performed with the Technical Assistants of Primary Health Care (ATAPS) (from the Social Security Fund of Talamanca), **has allowed us to learn more about behaviours and knowledge that communities have over the use of pesticides and allowed us to plan effective intervention strategies**.

OBJECTIVE 2: TO GAIN KNOWLEDGE ABOUT PESTICIDE EXPOSURE PATHWAYS AND LEVELS IN PREGNANT WOMEN WHO ARE PART OF BANANA AND PLANTAIN PRODUCTION SYSTEMS, AND UNDERSTAND HOW PRENATAL PESTICIDE EXPOSURES AFFECT HEALTH CONDITIONS AND NEURODEVELOPMENT OF THEIR NEWBORN CHILDREN.

STUDY DESIGN

To gain knowledge about pesticide exposure levels in pregnant women and to understand how prenatal pesticide exposure may affect newborns' health and neurodevelopment, we established a birth-cohort in Matina County between July 2010 and December 2011. We included 452 pregnant women and followed their newborns until having 1 year of age. In addition, to explore exposure pathways we measured pesticides and manganese in drinking water measured in a subset of women participating in the cohort study and measured pesticide exposure concentrations in environmental air of twelve primary schools from Matina County. Manganese was included because mancozeb, the most-used pesticide at banana plantations, contains approximately 20% manganese.

Initial results from environmental and biological samples, show what are possible pathways of environmental pesticide exposure, and what environmental, occupational and general factors explain measure pesticide exposure concentrations, and how prenatal exposures are related to infant's neurodevelopment measured at 1 year of age.

ENVIRONMENTAL EXPOSURE ROUTES

We detected presence of different pesticides in environmental air samples: chlorpyrifos (used in celestial bags to protect banana fruits from insects) was detected both in air samples of immersed and non-immersed schools. However, chlorpyrifos concentrations, on average, was almost five times higher in air of immersed schools compared to non-immersed schools: 9.5 ng/m^3 (p25=6.7; p75=12.3) versus 2.0 ng/m^3 (p25=0.5; p75=2.9) ($p < 0.001$ Wilcoxon / Kruskall-Wallis), respectively.

Pyrimethanil and fenprofimorph, fungicides applied using light aircrafts were detected more frequently in air samples from immersed schools versus non-immersed (Fisher's exact test $p = 0.004$ versus $p = 0.08$). In 90% of the samples of immersed schools and 67% of the samples of non-immersed schools, one of the nematicides or its metabolites (ethoprophos, terbufos, terbufos-sulfone) were detected (Fisher's exact test $p = 0.16$).

The concentrations of nematicides tended to be higher in air samples from immersed schools, as they exceeded limits of quantification more often; in 71% of the measurements of the immersed schools versus 33% of non- immersed schools (Fisher's exact test $p = 0.08$), respectively. In contrast, the insecticide diazinone was detected more frequently in the non-immersed villages (Fisher's exact test $p = 0.01$), which can be explained as one of the two villages of reference (Goshen), is located less than 2 km of pineapple produced in the canton of Limón.

The results of our study indicate that agricultural production systems on a large scale and with intense use of pesticides create an environmental exposure. Several pesticides are able to travel through air, as they were found at relatively long distances (> 1 km away).

In addition, large differences exist in drinking water supplies from different villages. Although most homes were connected to municipal water distribution systems, habitants of some villages depended on private wells. Out of 136 samples collected in the first sampling period, 17 had detectable levels of ethylene-thiourea (ETU) (> 0.15 µg / L), metabolite of the fungicide mancozeb. Concentrations ranged from 0.16 to 0.44 µg/L. Nine out of the 17 samples with detectable ETU concentrations were taken from water used for drinking or cooking. These results indicate surface and groundwater in some parts of Matina County may be contaminated with ETU; deep groundwater might also contain detectable levels of ETU.

From an environmental perspective, ETU contamination of water is worrying as it is a source that is difficult to renew. We consider it important to repeat and extend the study on water quality to confirm and deepen these findings. Nevertheless, drinking water does not appear to be a primary route of ETU exposure in this study population, as median urinary ETU concentrations in pregnant women were about 20 times higher. The photolysis half-lives of ETU in natural water are reported as 1 to 4 days, hydrolyzing in ethyleneurea (EU) and hydantoin (Xu S, 2000). This indicates that other routes of exposure such as air, dermal uptake, or food determine ETU exposure in pregnant women.

As the fungicide mancozeb contains about 20% manganese, the 136 samples from water used for human consumption were also analyzed for manganese (Hernández, 2011). With respect to water used for drinking or cooking (n = 111), 93 of the samples had detectable concentrations of manganese (≥ 0.03 µg /L). After data analysis (JMP 5.1 Recursive Partitioning), highest manganese concentrations were found in water from artesian wells from 4-Millas and Goshen, and in the system connected to a well located inside banana plantations that surround Bananita village, with an average 303.4µg / L (SD 132.1). In general, samples obtained from water originating from aqueducts had lower levels. The manganese concentrations in samples from wells are high and may cause neurodevelopmental problems reported in children exposed to comparable concentrations in Canada and Bangladesh.

It is unclear whether aerial spraying of mancozeb polluted water sources, whether manganese is naturally present in soil of Matina and therefore also in surface and ground water, or whether these high manganese water concentrations are due to a combination of both. A slight correlation between the levels of ETU and manganese in water (Spearman r = 0.24, p = 0.01), indicates that high manganese concentrations might be partly explained by weekly aerial spraying of mancozeb.

PESTICIDES CONCENTRATIONS AND METABOLITES IN PREGNANT WOMEN

During the first, second and third trimester of pregnancy, we collected samples of urine, blood and hair of 452 women, 445 women donated at least one urine sample: 440 women during the time of enrolment, 330 women during the second prenatal visit and 102 during the third prenatal visit. Urine samples were analyzed for ETU. On average, the levels were similar for the three trimesters of pregnancy.

Urinary ETU concentrations varied more between different measurement times than women, possibly reflecting influence of activities such as aerial spraying of mancozeb. There was a strong association between residential distance to the banana plantations and ETU level detected in the urine samples (p <0.0001) (see Figure 1).

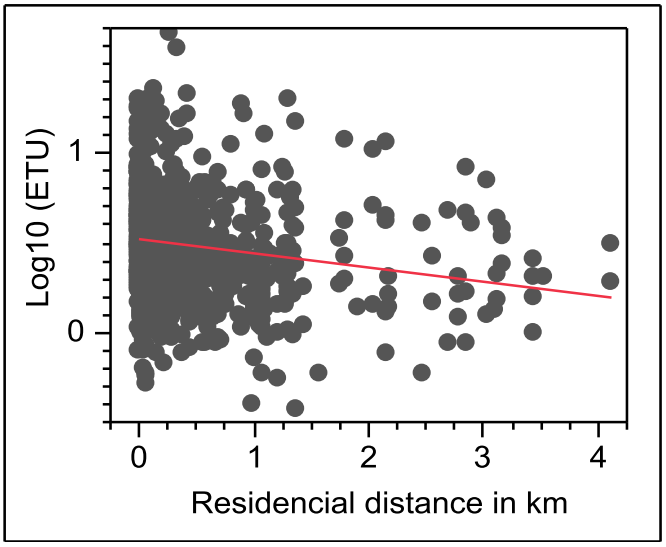


Figure 1. Urinary ETU concentrations (µg/g.cr) and residential distance to banana plantations (n=858, k=442) (log10 (ETU) = 0.52 – 0.08 (distance (km), p<0,0001)

Women working in agriculture had ETU concentrations higher (statistically significant) compared with those who did not (GM 3.7 vs 2.9 mg ETU / g.cr, p = 0.006). Women who washed clothes on the day of / previous to sampling, also had higher urinary ETU concentrations (GM 3.4 vs 2.8 mg ETU / g cr, p = 0.0006). Women who reported aerial spraying activities in the vicinity of their home the day of sampling had higher levels compared with women who did not (GM = 3.4 vs. 2.9 mg ETU / g.cr, p = 0.006).

It was estimated that for about 75% of the pregnant women their estimated daily intake (EDI) was above the chronic reference dose considered safe, established by Environmental Protection Agency of the United States (Figure 2, next page).

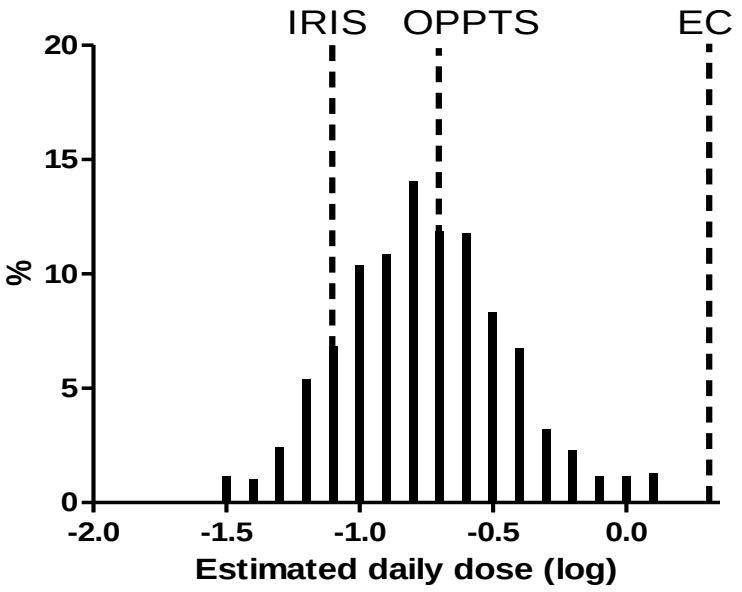


Figure 2. Estimated daily intake (log-scale), µg ETU/kg body weight/day in pregnant women from the ISA study, in relation to the chronic reference doses established by the Integrated Risk Information System (IRIS) and, the EPA Office of Prevention, Pesticides and Toxic Substances (OPPTS).

With respect to other pesticide metabolites, preliminary data (n=80) show some women had elevated urinary concentrations of TCPy (3,5,6-trichloro-2-pyridinol), a specific metabolite of chlorpyrifos used in bags to protect banana fruits, and OH-T (hydroxy-thiabendazole) a specific metabolite of thiabendazole a fungicide used at packing plants of banana plantations. The women with high concentrations worked in agriculture during pregnancy. In humans, prenatal exposure to chlorpyrifos has been associated with effects on child neurodevelopment while thiabendazole has been associated with teratogenic effects in animal studies.

Moreover, results from **manganese concentrations in pregnant women's hair and blood** indicate the following.

Manganese blood and hair concentrations maybe partly due to mancozeb exposure as:

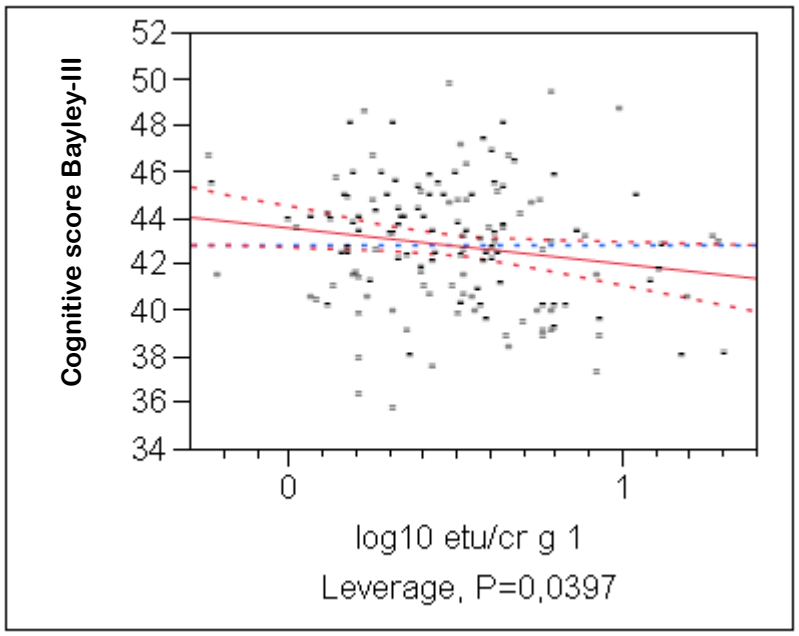
- Women living in houses with permeable walls / difficult to clean floors had higher manganese concentrations compared to women who did not live in such houses;
- Women living within 50 m of banana plantations have hair Mn concentrations higher (n = 112) compared to other (n = 331) (median: 2.43 mg / g vs. 1.62 mg / g, p <0.001 Wilcoxon / Kruskal Wallis Test (Rank sums));
- For those living closer to the plantations, 46.4% had hair Mn concentrations above 3 ug / g compared with 26.1% of those who live farther away;

- Women who have a spouse who works at a banana farm have higher levels of manganese in hair compared to women who did not (median: 1.85 mg / g vs. 1.31 mg / g, p <0.001 Wilcoxon / Kruskal-Wallis Test (Rank sums);
- Manganese hair concentrations slightly correlate with urinary ETU concentrations (Spearman r = 0.14, p = 0.0001).

Manganese hair concentrations correlated significantly with manganese concentrations in drinking water (Spearman's r = 0.45, p <0.0001). Apparently, water is a major route of manganese exposure. Manganese (II) is relatively stable in water and soluble.

NEUROLOGICAL EFFECTS ASSESSMENT AND NEURODEVELOPMENT

For the 356 children assessed at 12 months of age, preliminary results of the Bayley scale for children and child development (3rd edition), demonstrate an inverse relationship between urinary concentrations of ETU (Figure 3).



Preliminary findings also indicate a significant inverse relationship between maternal manganese hair concentrations during pregnancy and cognitive function in girls and social-emotional behaviour in boys (Figure 4, next page).

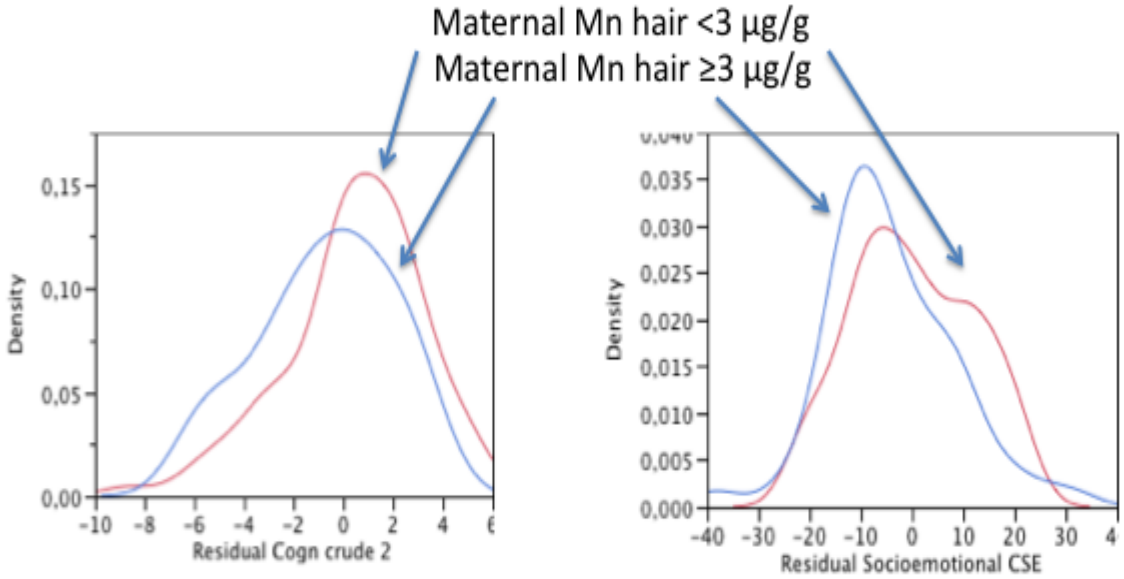


Figura 9. Densidad de las concentraciones de manganeso para la escala cognitiva (Bayley III) en niñas (izquierda) y la escala socio-emotional (Bayley III) en niños varones a las 12 meses de edad.

These findings clearly show the need to continue studying pesticide and manganese exposures to be able to understand its sources and its effects on children's neurodevelopment.

OBJECTIVE 3: TO ACHIEVE A REDUCTION OF PESTICIDE USE AND EXPOSURE IN COMMUNITIES WITH DIFFERENT TYPES OF BANANA AND PLANTAIN PRODUCTION SYSTEMS BY PILOTING DIFFERENT RISK REDUCTION ACTIVITIES …

COST-BENEFIT ANALYSIS OF CONVENTIONAL VERSUS AGROECOLOGICAL PRACTICES

Meetings were held with plantain farming and indigenous women organizations. Members of each organization selected their representative in the project. These farmers agreed upon managing a quarter of hectare with agro-ecological practices, whereas they continued managing the rest of their farm as before, using certain agrochemicals (conventional). In the conventional part of the farm a second quarter of hectare was marked. To be able to compare both production systems, in the centre of each parcel, a smaller area of 10 $m^2$was marked and in these areas measurements were performed to monitor plagues (Black Sigatoka, nematodes, bugs) and soil quality.

The results of activities performed within the context of this objective show it takes two to three years, until organically managed plantations produce economic benefits that are similar to conventional plantations. We can also observe that plantain smallholders' economical benefits in general are little. This can be partly explained by losses of plantain plants smallholders suffered due to flooding and strong winds. In addition,

intermediaries buy plantain at low and fluctuating prices. The costs of organic incentives were covered by the project, and prevented farmers from being economically negatively affected by participating in this project.

CONTROL OF FIJENSIS MYCOSPHAERELLA CONTROL (BLACK SIGATOKA)

Black Sigatoka disease was monitored during approximately 12 months in both agro-ecological and conventional plantain parcels, by documenting percentage of damage in each leaf from 10 plants located in the center of each parcel. Results of both parcels were compared by calculating average percentages of damage in leaf four and five, using the Pearson's Chi-Square Test. With respect to the two parcels located in the indigenous territory, on average, Sigatoka disease in leaf 4 and 5 did not exceed 10% of leaf area; results were similar for agro-ecological and conventional parcels.

In the parcels located outside indigenous territories, leafs of plantains from agro-ecological parcels had about a 5% higher mean percentage of damage than conventional parcels. This might be explained by the fact that these parcels had less shade than the parcels located in indigenous territories and therefore more susceptible to diseases such as Sigatoka. Nevertheless, the percentage of damage is relatively low and unlikely to affect plantain production.

These results evidence agro-ecological and cultural practices such as application of efficient microorganisms (EM) efficiently control Sigatoka disease, and form a feasible and healthy alternative to chemical pesticides for the control of Sigatoka.

CONTROL OF POPULATIONS OF NEMATODES

The study of nematodes was based on monitoring of populations of nematodes present in soil and root samples taken in the parcels of the four producers. In the four plots populations of Radopholus similis, Helicotylenchus spp., Meloidogyne spp. and Pratylenchus spp. were most common.
The results demonstrate populations of parasitic nematodes in samples from soil and plantain roots obtained in the four agro-ecological parcels are well controlled, and do not reach critical levels of 1000 or 2000 nematodes in 10 g of roots. Nematode populations over time even tended to be somewhat lower in parcels with an agro-ecological management (applying efficient microorganisms and improving soil quality) compared to conventional management based on pesticide use These results are consistent with literature; a constant incorporation of organic amendments promotes health and vigor of plantain and banana roots.

The results of this project evidence that in smallholders' plantain farms it is not necessary to apply highly toxic pesticides to control nematicides.

CONTROL COSMOPOLITES SORDIDUS (GERMAR) BANANA ROOT BORER

Populations of banana root borers were monitored every 3 months in agroecological and conventional parcels, by putting four to five 'cookies' made from slices of plantain truncks with a piece of plantain leave in the centre at four to five spots in each parcels.

MAYOR ACHIEVEMENTS - OUTCOMES

OUTCOMES

1. ISA TEAM MEMBERS CONTRIBUTE TO A MORE COMPREHENSIVEUNDERSTANDING OF AGRICULTURAL PRODUCTION SYSTEMS

During the development of the project, team members grew both academically and personally, and were each time more capable to contribute to a more comprehensive understanding of the issues studied. This was also the case for partners such as members from community organizations and governmental representatives, for example from the Costa Rica Social Health Security (CCSS), who increasingly participated more actively and contributed with new knowledge to an integral understanding of conventional agricultural production systems that include extensive pesticide use. Through training and better understanding of these production systems team members are now able to integrate and articulate project activities very well, which strengthens and deepens existing knowledge and results in meaningful learning at academic, political and community levels.

2. THE COMMUNITY OF 4-MILLAS IDENTIFIED THE IMPORTANCE OF CHANGES TO IMPROVE DRINKING WATER QUALITY

We were able to establish collaboration with a representative group of the community of 4-Millas in Matina, Limón province who have started to develop actions to improve drinking water quality of this community. During several working sessions community members have expressed appreciation working in a participatory way and the importance of creating actions for common good. They also recognize that the community itself, as a social actor, needs to actively promote and manage these improvements.

3. COMMUNITY ORGANIZATIONS FROM 4-MILLAS HAVE STARTED TO ACTIVELY SEARCH GOVERNMENTAL SUPPORT TO IMPLEMENT IMPROVEMENTS WITH RESPECT TO DRINKING WATER QUALITY

In March 2013, community leaders of 4-Millas, managed to obtain a technical visit by the National Institute of Water (AyA for its acronym in Spanish) and a perforation of a potential well was revised. Pending the results of the second water sampling that we performed in this community in April 2013, community representatives

have decided to use these results to meet with AyA and address the issue of water supply. We (ISA-team) met with the local AyA representative before starting our work in 4-Millas; he also recommended us to start analyzing drinking water quality with more detail in 4-Millas.

The Ecosystem Approach to Human Health has allowed development of skills in the ISA team through which we achieved active collaborations with civil society and governmental representatives. It allowed the strengthening of partnerships and the development of a shared vision as a response to problems that were discussed jointly.

4. IN MATINA 450 FAMILIES, COMMUNITY WATER BOARDS (ASADAS), GOVERNMENTAL ORGANIZATIONS HAVE BEEN SENSITIZED ABOUT PROBLEMS OF PESTICIDE USE

We have raised awareness in women participating in the birth-cohort study and their families about problems pesticides generate for environment and health. These women have shown interest in continuing their participation and in general are concerned about how pesticides may affect their own and their children's health. Civil society groups such as community water boards (ASADAS, for its acronym in Spanish) and Governmental institutions such as Ministry of Health, Institute of Aqueducts and Sewers (AyA, for its acronym in Spanish) and Ministry of Education have expressed interest in learning more about the results of our project and have asked us to present results of this project in an inter-institutional governmental committee in Matina and Limon province.

5. PLANTAIN PRODUCERS ACTIVELY PARTICIPATE IN THE PROJECT AND CONTRIBUTE TO DISCUSSIONS ON AGRO-ECOLOGICAL FARMING

Producers of the project involved validating agro-ecological practices were integrated as part of the ISA team and contribute to discussions on agro-ecological practice. During workshops, producers have shared their opinion and agree upon the necessity to reduce pesticide use and promote agro-ecological production systems. **Plantain producers are compromised to disseminate results of the project and express interest in promoting agro-ecological practices to other producers.**

6. PLANTAIN PRODUCERS WHO PARTICIPATE IN THE PROJECT ESTABLISH ADDITIONAL COLLABORATIONS TO EXTENT LEARNING AND IMPLEMENTION OF AGRO-ECOLOGICAL PRACTICES

Plantain producers from Paraíso (non-indigenous part of Talamanca) have established additional collaborations with the International Union for Conservation of Nature and Ministry of Agriculture to continue the learning, implementation and validation of agro-ecological practices.

7. THE SON OF ONE OF THE PRODUCERS DECIDED TO MANAGE HIS WHOLE PARCEL WITH CULTURAL AND AGRO-ECOLOGICAL PRACTICES

The son of one of the producers (indigenous territory) decided to change his entire parcel of 1 hectare and stop using pesticides. In August 2012 he took this decision after observing that agro-ecological management allowed him to produce plantains of same quality compared to conventional production using pesticides.

8. AT A REGIONAL LEVEL, STATE INSTITUTIONS SUCH AS COSTA RICAN SOCIAL SECURITY (CCSS) CONFIRM THEIR COMMITMENT AND SUPPORT DISSEMINATION ACTIVITIES ON PESTICIDE RISKS AND ALTERNATIVES TO PESTICIDE USE

In March 2013, we resumed our work with health technicians from the CCSS (ATAPs, for its acronym in Spanish) and continued participatory training of ATAPs who continued their dissemination activities on pesticide risks and alternatives to pesticide use. In addition, the director of CCSS in Talamanca proposed to develop jointly and instrument to do a census on pesticide usage, knowledge and behaviour in the indigenous territories. This questionnaire will be designed jointly with the ATAPS, to promote its application o a longer term and to allow the incorporation of pesticide risks as part of continuous health promotion activities in communities in the upper Talamanca region.

9. ISA TEAM MEMBERS INTEGRATE DIFFERENT AREAS OF KNOWLEDGE AND INCREASE UNDERSTANDING OF PESTICIDE USE, RISK PERCEPTION AND ALTERNATIVES TO PESTICIDE USE

During the performance of the project, team members have built new areas of knowledge and have learned to combine disciplines, indigenous and popular knowledge to achieve a more complete understanding of pesticide use, risk perception, health risks and alternatives to pesticide use

Team members have been able to approach community groups and integrate community members' and academic knowledge to bridge different realities, and have promoted participatory processes aimed at looking for solutions and effective interventions. Examples are: the work done in 4-Millas of Matina and the work with ATAPS in the Talamanca County. **We achieved trans-disciplinarity, which characterizes a project that applies an ecosystem health approach.**

IMPACTS OF THE PROJECT

IMPACT 1: PESTICIDES INCLUDED IN AGENDA OF CCSS - TALAMANCA

We have established an active collaboration with the Costa Rica Social Security (CCSS) in the Talamanca region and have supported formation of ATAPs. After two years of training and outreach activities to communities in collaboration ATAPS, the CCSS has expressed interest to include pesticides and its impact on health in the Integrated Analysis of Health Attention (ASIS, for its acronym in Spanish). ASIS is an analysis performed on a yearly basis by CCSS to describe populations' health and social context.

IMPACT 2: SUSTAINABILITY OF ISA PROGRAM

In 2011, the ISA project was transformed into a Program of the Central American Institute for Studies on Toxic Substances (IRET) with the possibility to be renewed in 2016. This transformation is a major impact as it allows us to continue with certain activities in Matina and Talamanca, also after IDRC funding will be finished.

IMPACT 3: VISIBILITY OF PESTICIDES AS AN ENVIRONMENT HEALTH RISK AND START OF PESTICIDE USE REDUCTION

At a population level, persons have become aware of environmental health problems due to pesticide use and learned about the existence of agro-ecological alternatives to pesticide use. Apart from the farmers who directly participated in the project, additional community members have started to: 1) reduce pesticide use and 2) to use alternative pest control methods. This was a result of a process of research and constant community outreach activities in the Talamanca County, that have been performed since 2006 when we started working in this County.

IMPACT 4: AWARENESS OF SOCIAL ACTORS ON THE THEME OF PESTICIDES

At local governmental levels, representatives recognize that pesticides pose a health and environmental problem. The Institute of Aqueducts and Sewers (AyA) in Matina learned pesticides contaminate drinking water, and recognized validity of water sampling conducted our project; the Ministry of Health in Matina requested information on the progress of the study and suggested that the findings were presented in an inter-institutional committee of governmental institutions in Matina County and Limón Province.

PRODUCTS OF THE ISA PROJECT

1. TO UNDERSTAND THE SOCIO-ECONOMIC AND ECOLOGICAL CONTEXT OF CURRENT BANANA AND PLANTAIN PRODUCTION SYSTEMS, HOW THIS CONTEXT RELATES TO PESTICIDE USE AND EXPOSURE, AND HOW RISKS AND RISK REDUCTION STRATEGIES ARE PERCEIVED BY DIFFERENT STAKEHOLDERS;

Two papers published, two papers in preparation, one technical report, one report of a bachiller's graduation project, one master's thesis, one doctoral thesis proposal

1. *Pesticide use in banana and plantain production and risk perception among local actors in Talamanca, Costa Rica.* **Barraza D, Jansen K, van Wendel de Joode B, Wesseling C.** Environmental Research 111 (2011) 708–717.
2. *Social movements and risk perception: Unions, Churches, Pesticides and Bananas in Costa Rica.* **Barraza D, Jansen K, van Wendel de Joode B, Wesseling C.** International Journal of Occupational and Environmental Health. 2013 January 2013 VOL. 19 N°. 1.
3. *Pesticide risks perception among education workers/ school personnel in the banana region of Limón, Costa Rica*. **Barraza D et al**. Artículo en proceso, será sometido en la revista Risk Analysis.
4. *Percepción de la relación trabajo y salud de trabajadores y trabajadoras bananeras y sus familias en el cantón de Matina, Costa Rica 2009-2010*". **Camilo Cano JC** et al. Artículo en proceso.
5. *Análisis general del cantón de Talamanca como base para el desarrollo de la etapa de validación de alternativas agroecológicas al uso de agroquímicos en el cultivo de plátano.* **Díaz M**. Informe técnico 2 Infantes y Salud Ambiental (ISA-02), Instituto Regional de Estudios en Sustancias Tóxicas (IRET), Universidad Nacional, 2011.
6. *El uso de las bolsas plásticas tratadas con el insecticida clorpirifos en la producción de plátano en los territorios indígenas Bribri – Cabécar.* **Carranza J.** Informe final de Práctica Dirigida para optar por el título de Bachiller en Manejo de Recursos Naturales, Universidad Estatal a Distancia, Setiembre 2011.
7. *Grasping the blue bags - A settings approach to perceptions on chlorpyrifos-treated bags in plantain production (Costa Rica).* **Wentink C**. Thesis MSc. Health and Society, Wageningen University, Netherlands April 2012.
8. *From ecosystem services to ecosystem benefits: Managing trade-offs in human well-being in agricultural communities in Costa Rica* **Berbés-Blázquez M,** PhD Thesis Proposal, 2011, University of York, Canada.

2. TO GAIN KNOWLEDGE ABOUT PESTICIDE EXPOSURE PATHWAYS AND LEVELS IN PREGNANT WOMEN WHO ARE PART OF BANANA AND PLANTAIN PRODUCTION SYSTEMS, AND UNDERSTAND HOW PRENATAL PESTICIDE EXPOSURES AFFECT HEALTH CONDITIONS AND NEURODEVELOPMENT OF THEIR NEWBORN CHILDREN

Two papers published, two papers in preparation, one technical report, one report of a bachiller's graduation project, one master's thesis, two doctoral thesis proposal,

1. *Indigenous children living nearby plantations with chlorpyrifos-treated bags have elevated 3,5,6-trichloro-2-pyridinol (TCPy) urinary concentrations. Van Wendel de Joode B, Barraza Environmental Research 117 (2012) 17–26.*
2. *Aerial application of mancozeb is associated with elevated urinary ethylene thiourea (ETU) concentrations in pregnant women: the Infant Environmental Health Study (ISA). Van Wendel de Joode B et al. En preparación.*
3. *Blood and hair manganese concentrations in pregnant women living near banana plantations in Costa Rica: results from the ISA study. Mora AM et al. en preparación.*
4. *Drinking water and pesticides in banana growing areas Contamination of water sources with ethylenethiourea (ETU)in Matina County, Costa Rica. Skytt A. Environmental Science Degree project, Bachelor of Science, Lund University, Sweden, 2011.*
5. *Caracterización de sistemas de agua y evaluación por posible contaminación con plaguicidas en aguas para consumo humano. Matina, Limón. En una muestra de mujeres que forman parte del Programa Infantes y Salud Ambiental (ISA). Práctica Profesional Supervisada del Bachillerato en Gestión Ambiental, Facultad de Ciencias de la Tierra y el Mar, Escuela de Ciencias Ambientales. Hernández Víquez C, Heredia, noviembre 2011.*
6. *"Propuesta de tecnología limpia para disminuir los niveles de manganeso en agua provenientes de pozos, comunidades de 4 Millas, Goshen y Bananita, Matina". Licenciatura en Gestión Ambiental, Universidad Nacional de Costa Rica. Claudia Hernández. Está ejecutando su trabajo final de graduación para optar por el grado de licenciatura en Gestión Ambiental. 2013.*
7. *Evaluación de la exposición ambiental por plaguicidas en 12 escuelas del Cantón de Matina. Córdoba, L. Maestría en Salud Pública, Universidad de Costa Rica. en preparación.*
8. *Impact of the quality of caregiver-child interactions on neurodevelopmental outcomes in infants prenatally exposed to pesticides in banana-growing areas in Costa Rica. Dudani A. PhD candidate, Psychology (Clinical-developmental) Supervisor: Dr. Christine Till. May 15th, 2012.*
9. *PhD Thesis Proposal in Epidemiology. Mora AM University of California at Berkeley, United States of America. Supervisor: Prof Dr. Brenda Eskenazi.*

Seven informative materials available at http://www.isa.una.ac.cr

1. *Alternativas para UNA producción limpia de plátano en Talamanca*
2. *Contacto con plaguicidas y efectos en la salud respiratoria de las mujeres del territorio indígena*
3. *Cuidado con los plaguicidas*
4. *Elaboración de abono foliar orgánico*
5. *Elaboración de abono orgánico sólido o tierra fermentada*
6. *Material informativo: los plaguicidas*
7. *Resultados del estudio: los plaguicidas y sus efectos sobre la salud*

3. TO ACHIEVE A REDUCTION OF PESTICIDE USE AND EXPOSURE IN COMMUNITIES WITH DIFFERENT TYPES OF BANANA AND PLANTAIN PRODUCTION SYSTEMS BY PILOTING DIFFERENT RISK REDUCTION ACTIVITIES ...

One tecnical report: *Condiciones del suelo y poblaciones de nemátodos en cinco parcelas demostrativas en las comunidades de Shiroles y Paraíso*, Talamanca. Informe técnico 1 Infantes y Salud Ambiental (ISA-01), Instituto Regional de Estudios en Sustancias Tóxicas (IRET), Universidad Nacional, Díaz M, Peraza W, Córdoba C, van Wendel de Joode B, Mayo, 2011.

One report of a bachiller's graduation Project: *Plan integral para el manejo agroecológico de plantaciones de Plátano (Musa sp.) en la zona de Talamanca, Limón*. **Víquez R.** Diciembre 2012.

Four parcels with agroecological management

A data base with performed analysis on Sigatoka disease during one year in plantain comparing agor-ecological and conventional management systems.

A database on nematode populations during three years in agroecological versus conventional parcels.

A database on populations of banana root borers, monitored during one year in agroecological versus conventional parcels.

A set of informative materials on alternatives to pesticide use, for an environmental healthy plantain production in Talamanca:
http://www.isa.una.ac.cr/index.php?option=com_remository&Itemid=13&func=select&id=2

Partnerships to create political impact measures and strategies for risk reduction, such as local governments and indigenous Bribri Cabécar (ADITIBRI and ADITICA), the Social Security Fund (CCSS) of Talamanca, Ministry of Education.

4. TO STRENGTHEN ECOHEALTH RESEARCH CAPACITY IN COSTA RICA IN THE CONTEXT OF AN INTERNATIONAL COLLABORATIVE RESEARCH GROUP.

Academic formation of six ISA-team members and additional students who are partly (co)supervised by academics from the Netherlands and the United States:

- Douglas Barraza. PhD in Social Antropology, TAO Group, Wageningen University, Netherlands.
- Ana María Mora. "*Prenatal mancozeb exposure, fetal growth and children's neurodevelopment in Limón, Costa Rica*". PhD, University of California at Berkeley, United Stated of America.

- Juan Camilo Cano. "*Percepción de la relación trabajo y salud de trabajadores y trabajadoras bananeras y sus familias en el cantón de Matina, Costa Rica 2009-2010*". Maestría en Salud Pública, Universidad de Costa Rica.

- Leonel Córdoba. "*Evaluación de la exposición por plaguicidas en 12 escuelas del Cantón de Matina*". Maestría en Salud Pública, Universidad de Costa Rica.

- Rosario Quesada. Maestría en Epidemiología. Universidad Nacional de Costa Rica.

- Claudia Hernández*. "Caracterización de sistemas de agua y evaluación por posible contaminación con plaguicidas en aguas para consumos humano, Matina, Limón en una muestra de mujeres que participan de la cohorte del Programa Infantes y Salud Ambiental (ISA)".* Informe final de bachillerato. Licenciatura en Gestión Ambiental, Universidad Nacional de Costa Rica. Tutora Berna van Wendel. 2011.

- Claudia Hernández. "*Propuesta de tecnología limpia para disminuir los niveles de manganeso en agua provenientes de pozos, comunidades de 4 Millas, Goshen y Bananita, Matina*". Licenciatura en Gestión Ambiental, Universidad Nacional de Costa Rica. Proyecto en ejecución. Tutora Berna van Wendel.

- Seven additional thesis/graduation projects performed within the ISA Project: **Hernández Víquez C , Víquez R, Carranza J, Berbés-Blázquez M, Dudani A, Wentink C, Goris K and Skytt A in** which co**l**laborated academics from Costa Rican and other countries: Escuela Ciencias Agrarias y Escuela de Educación Ambiental, Universidad Nacional, Costa Rica; Universidad Estatal a Distancia, Costa Rica; York University Canada, Wageningen University, Netherlands; Utrecht University, Netherlands; Lund University, Sweden.

OVERALL ASSESSMENT AND RECOMMENDATIONS

This project has generated important new knowledge and rich experiences. Results on environmental and personal pesticide exposure levels and manganese, and its effects on infants' neurodevelopment are worrisome and there is a clear need to follow-up on the findings of this study. We were able to extend and profound our knowledge on pathways of exposure. This, together with the results of the studies on risks perceptions and social-economical contexts helped us to start promoting feasible interventions. Risk reduction in particular is feasible because findings of agro-ecological farming methods showed that plagues can be controlled with natural products. Changes take time and could only partly be implemented during the duration of this Project. Therefore, to obtain a larger impact of Project results, **we recommend IDRC to fund a second fase, to allow us to work jointly with diverse community groups and governmental institutions on interventions measures that need to be monitored and evaluated.**

The construction of knowledge is a capability that team members have acquired during the performance of the Project. They have communicated with social actors horizontally, and have respected popular perceptions and

knowledge, which allowed them to integrate different kind of knowledge and to propose joint solutions in response to the identified problems. Examples of this are work with: 1) the community of 4-Millas in in Matina; 2) Technical Assistants Primary Health Care (ATAPS); plantain smallholders and their organizations to implement alternatives to pesticide use in Talamanca.

The participatory approach that we used in the Project, allowed us to understand that the link between university researchers and civil society, is key to risk management and necessary to impact behavioral changes and practices y reduction of toxic exposures from the source. **This seems to be particularly true for less developed countries with weaker environmental regulations that are less enforced compared to developed countries.**

ISA researchers have proven to be a group that strives to keep the ISA Program running and were able to obtain complementary sources of funding and extend research activities, such as the determination of manganes in prenatal blood and hair samples.

Our knowledge is recognized by other research groups, such as John Benavides, coordinator of a course on EcoHealth, Social Medicine and Public Health as part of the Masters in Public Health and Social Security of the '*Universidad Escuela de Administración de Negocios de Bogotá*', Colombia. John has invited ISA-researchers to share their experiences with students and other academic, during events organized by this university on several occasions. Their main interest was to learn how we integrated the components of human health with the component of agro-ecological alternatives.

When finalizing this study, we expected IDRC would be interested in financing a second phase, given the many outcomes and impacts that were obtained in a relatively short period of time, with a moderate budget. It has become a main challenge now to continue with our research, as only few organizations fund integrated projects such as ISA. Because of this, the ISA-team has started to disintegrate, as there are insufficient resources to finance the team. The ISA Program Coordinator is trying to find support at the Universidad Nacional, to be able to continue Program activities and keep part of the team members.

Our main target for the near future is to publish the results generated by this Project as son as possible in academic and popular journals. During scientific, community, political meetings, we have learned there is much interest in knowing the results of this unique Project, nationally, regionally and internationally.

From this evaluation, we recommend IDRC to offer the possibility of developing a specific project within the ISA program to follow up on activities and to achieve greater impact in promoting systems of banana and plantain production that are healthy for humans and their environment, while obtaining similar economical benefits. We also recommended IDRC to offer financial support for dissemination activities such as preparation of additional informative materials and a documentary, allowing dissemination of results generate by the ISA Project nationally, regionally as well as internationally.