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Increasing IPM Knowledge Through FFS in Benin

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1. Introduction

Over the next two generations 4 billion more people will live in cities, increasing the proportion of the urban population from 50 to 80 per cent of the total world population (NRC, 1999). Thus a sustainable development needs to focus on meeting the needs of an increasing human population, reducing poverty and hunger while at the same time sustaining the life support systems of the planet (NRC, 1999). While the Green Revolution technologies enabled extensive monocultures and higher yields through improved seeds, chemical fertilizers and synthetic pesticides, biodiversity in and around the agro-ecosystems have been reduced, causing the loss of natural pest and disease control (Gallagher et al., 2005). This has increased the need for synthetic pesticides in the agricultural sector to the current global use of 2.56 billion $kgyr^{-1}$ (Pretty, 2008), with associated negative effects for humans and the ecosystem becoming evident. While the externalities of pesticides in rice systems in China cost $1.4 billion per year through adverse effects on biodiversity and people's health (Norse et al., 2001), the annual mortality rate due to pesticides in the remote Ecuadorian highlands is among the world's highest, 21 per 100 000 people (Sherwood et al., 2005). On the other hand, in the Philippines, agricultural systems that do not use any synthetic pesticides experience higher net social benefits due to reduced illnesses among farmers and their families, and associated lower medical costs (Rola & Pingali, 1993, Pingali & Roger, 1995). According to FAO and ILO estimates, 2 to 5 million agricultural workers yearly experience severe pesticide poisoning and related illnesses of which 40 000 are lethal (FAO & ILO, 2009). However, pesticide poisoning incidents are often underreported, as indicated by a study among farmers in Senegal, Mali and Benin, where over 80% of the respondents faced adverse effects after spraying pesticides, to the extent of blurred vision, unconsciousness or severe dizziness, but only 2% sought medical attention for these symptoms (Thiam & Touni, 2009). Thus recent studies, where 4% to 9% of the surveyed farmers reported poisoning incidents the last year, estimate a yearly 25 – 45 million poisoning cases (Kishi, 2005).

Africa only accounts for 4% of pesticides used globally, an estimated 75-100 metric tons of pesticide active ingredient (compared to 350,000 tons in Europe), and average pesticide use per hectare cultivated land in Africa (1.23kg/ha) is very low compared to Latin America and Asia (7.17kg/ha and 3.12kg/ha respectively) (Thiam & Touni, 2009). Still, the risks and impacts associated with synthetic pesticides are not necessarily lower in Africa as many of the pesticides used in the continent are adulterated, poor quality and unlabelled and application and handling practices are often highly unsafe (Thiam & Touni, 2009, Lund et al., 2010). In a study among farm families in Senegal and Benin, the number of pesticide poisoning incidents were 619 and 84 respectively of which 16% and 23% were fatal (Thiam & Touni, 2009). Only 2% of the farmers in the studied villages used a full set of protective gear (gloves, boots, and masks or glasses), showing how unavailability and impracticality of protective gear has an enormous impact on poisoning levels and farmers' health (ibid.). The farmers' families and communities also experienced negative effects of pesticides, like accidental poisonings, because pesticides are often stored freely available in kitchen or bedrooms, empty pesticide containers are reused for food and drinks and pesticides are purchased in non-original containers (ibid.). Governments tend to focus on the ones handling pesticides directly assuming that those face the highest poisoning risk, but data from Benin, Senegal, Ethiopia (ibid.), Ecuador (Cole et al., 2002) and India (Mancini et al., 2005) shows high frequencies of pesticide poisonings among women and children even though they are generally not applying pesticides.

The World Health Organization (WHO) has classified pesticides in Ia (extremely hazardous), Ib (highly hazardous), II (moderately hazardous), III (slightly hazardous) and unlikely hazardous.There is increasing pressure from and work done by government regulators and civil society to prohibit the use of the Class Ia and Ib pesticides (Thiam & Touni, 2009). The frequent incidents of acute and fatal poisonings from Class II pesticides in Benin and Senegal, illustrates the dangerous effects of even "moderately hazardous" pesticides in conditions of poverty and poor education, showing that also Class II and Class III compounds (e.g. malathion) should be considered for restrictions (ibid.). The Persistent Organic Pollutant Endosulfan (Class II), which has been widely used in West African cotton growing areas, was banned by governments in the region in 2008, as it had been associated with acute and fatal poisonings (ibid.). Pesticides cause long-term health problems such as birth defects and cancers (Lichtenberg, 1992) and several studies link pesticide exposure to respiratory problems, memory disorders (Arcury et al., 2003), dermatologic conditions (O'Malley, 1997), anxiety, depression (Beseler et al., 2008), and neurological disorders (Ascherio et al., 2006). WHO estimated that long-term exposure to pesticides may result in a yearly 735,000 people globally suffering specific chronic defects and 37,000 cases of cancer (WHO, 1990). Thus also health Ministries in six Central American countries have proposed a regional ban on the Class II pesticides endosulfan, paraquat and chlorpyrifos, in addition to pesticides in class 1a and 1b, based on results from an eight year poisoning surveillance program (Rosenthal, 2005).

Pesticide residues may interfere with the legume-rhizobium chemical signalling reducing nitrogen fixation and crop yields (Fox et al., 2007), and over 95% of applied herbicides and 98% of insecticides reach other destinations than their target, including non-target species, water, air, bottom sediments, and food (Miller & Spoolman, 2009). The use of synthetic pesticides among vegetable producers in urban and peri-urban areas of West-Africa has increased to the extent that certain insect pests have developed resistance to the pesticides (Atcha-Ahowé et al., 2009). Additional negative effects are increasing insecticide resistance in insect vectors due to the leakage of insecticides to mosquito breeding sites (Akogbeto et al., 2008), to the extent that insecticide resistance in Anopheles mosquitoes is threatening the success of malaria control programs (Djouaka et al., 2005), and pesticide resistance in target pests has made pest resurgence a common phenomenon in cotton, vegetables, rice and fruit crops production systems (Lim, 1992). Recent research also indicates that toxic compounds

may be dispersed to even remote areas via atmospheric deposition (Rosendahl et al., 2009). In West-Africa, agricultural land is being degraded by poor agricultural practices and the use of chemical products (Pimbert et al., 2010). Still, African farmers often use credit to buy inputs such as seeds, fertilizers and synthetic pesticides at high costs, making them dependent on good yields to break even and manage their debts (Williamson, 2003). In this situation, many may get caught in the pesticide treadmill where they do not dare to reduce the use of synthetic pesticides for fear of yield loss. While the externally funded West-African agricultural research system increasingly focus on the use of imported fertilizers and pesticides, the use of traditional seeds and organic manure is declining and small-scale producers have felt lack of citizen control over knowledge production (Pimbert et al., 2010). January 2006, the local government of Sikasso in Mali hosted the Citizen Space for Democratic Deliberation on GMOs and the Future of Farming in Mali where local farmers made policy recommendations based on expert evidence from various sources (ibid.). The farmers requested a re-orientation of public research from the current focus on input-intensive farming and GM seeds, towards ecological farming not requiring chemical inputs, improved local seeds and landraces, regeneration of local markets and food systems, supporting small-scale producers. They also suggested that farmers set the research objectives and called for more exchange between farmers and researchers as well as the development of new Integrated Pest Management (IPM) strategies and training in these strategies taking local knowledge into account (ibid.). Also the recent International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) panel supported by over 400 experts under the co-sponsorship of the FAO, GEF, UNDP, UNEP, UNESCO, the World Bank and WHO, called for new farmer-scientist partnerships, to improve understanding of agro-ecology, i.e. by IPM, and develop an integrated agro-ecosystem and human health approach to enhance food security and safety, stating that: “The way the world grows its food will have to change radically to better serve the poor and hungry if the world is to cope with growing population and climate change while avoiding social breakdown and environmental collapse” (McIntyre et al., 2009). A recent UNEP and UNCTAD report based on 24 African countries states a 100% yield increase with organic or near-organic practices, concluding that organic practices in Africa outperformed industrial, chemical-intensive conventional farming and in addition improved soil fertility, water retention and draught resistance, making it a promising approach for food security in the continent (UNEP & UNCTAD, 2008).
As the ‘top-down’ recommendations for pest control, have often failed to reduce pest damage, pesticide use or enable farmers to learn about IPM (Williamson, 1998), there is a need for new ways of learning (Orr, 1992, Bentley et al., 2003, Liebelin et al., 2004, Bawden, 2005, Chambers, 2005). One learning method focusing on the farmers’ own development is the farmer field school (FFS), which is increasingly being used to promote IPM. Since IPM-FFS was introduced by the Global IPM Facility in West Africa (Ghana) in 1996, it has spread to over a dozen countries, from Senegal to South Africa (WB, 2004). IPM-FFS has been adopted in the national policies in Mali, Burkina Faso and Senegal, and IPM curricula, initially made for rice, have been developed for other crops including vegetables (ibid.). Community IPM, which has been used to increase the community involvement and adaptation of IPM in Asia for 15 years, is now being tested in Africa, including Burkina Faso, Ghana, Mali and Senegal in West Africa (ibid.). In 2003, the International Institute of

Tropical Agriculture (IITA) initiated the project 'Healthy Vegetables through Participatory Integrated Pest Management (IPM) in Peri-urban Gardens of Benin' (hereafter referred to as the project) to enhance farmers' efforts to produce quality vegetables through informed decisions on the choice and use of IPM options (James et al., 2006). The project was unique as it was the first time that a vegetable FFS was conducted by IITA in West Africa. This chapter will discuss the effects of IPM-FFS in pest management, including the IITA vegetable IPM-FFS as a case study.

2. The use of IPM and FFS in pest management

2.1 IPM and FFS

Mature ecosystems' state of dynamic equilibrium buffers against large shocks and stress, but modern agro-ecosystems have weak resilience (ability to resist stress and shocks) (Holling et al., 1998, Folke, 2006, Shennan, 2008). Thus developing sustainability requires a focus on structures and functions to improve the resilience, such as increasing the biodiversity to recreate natural pest and disease control, rather than seeking to eliminate those populations (ibid). In ecosystems, multi-trophic interactions are vital (Shennan, 2008). For example foliar herbivory in grasslands impact the functions of soil food webs (Wardle, 2006), which, together with changed nutrient dynamics, in turn affect the plant attractiveness to herbivores (Awmack & Leather, 2002, Beanland et al., 2003). Also due to the crops' systemic defense mechanisms above-ground attack may trigger responses to below-ground attack and vice versa (Bruce & Pickett, 2007). These complex crop–weed–disease–pest interactions imply that farm practices such as crop rotation, tillage, pesticides and fertilizers affect disease incidence, weed and pest populations (Bruce & Pickett, 2007), while practices like utilizing nitrogen fixing legumes, natural enemies for pest management and applying zero-tillage may enhance the sustainability (Pretty, 2008). As the importance of the complex interrelationships between the crop, weed, disease and pests is increasingly documented, the reductionist view of applying a synthetic pesticide to fix a specific pest problem is being questioned (NRC, 2010). Thus the pressure for pesticide reductions has influenced research to shift its focus towards non-chemical alternatives (ibid.). Increased emphasize is being paid to the approach Integrated Pest Management (IPM), which appreciates the complexity of the agro-ecosystem and "utilizes all suitable techniques in the socioeconomic, environment and population dynamics context of farming systems in a compatible manner to maintain pest population levels below those causing economic injury" (Dent, 1995: 1). IPM has proved able to reduce or eliminate the use of synthetic pesticides while improving the natural capital in and around agro-ecosystems (Lewis et al., 1997). However, the understanding of IPM varies, so while FAO recently changed its definition of IPM towards greater emphasis on ecologically based management, with pesticides as a last option (W. Settle, presentation to the committee on January 14, 2009 in NRC, 2010), other actors continue to use a narrower definition focusing on improved pesticide use (Shennan et al., 2001).

In pest management, proper soil maintenance to support the microbial, fungal, and nematode community suppressing pathogenic fungi and nematodes, inducing crop resistance responses, and reducing viable weed seed populations is important. Biological control has proven successful for arthropod pest management (NRC, 2010), like the introduction of the parasitoid *Epidinocarsis lopezi* controlling the mealy bug *Phenacoccus manihoti* attacking cassava in Africa (Neuenschwander et al., 2003). Bio-pesticides require that users understand they are working with biological processes or living organisms (Waage, 1996). Thus poor understanding of the function of microbal agents, influenced by the marketing of bio-pesticides as biological versions of conventional pesticides, has reduced the usefulness of many microbial agents (ibid). However, to convince farmers about the value of bio-pesticides and make them choose it over chemical products, the farmers need to be able to assess the impact of the control agent (Williamson, 1997). Conservation biological control enhances indigenous populations of natural enemies such as insects, spiders, and other arthropods by providing habitat in the field (Shennan, 2008), or by planting hedgerows (Letourneau, 1998, Letourneau & Bothwell, 2008, Nicholls et al., 2001). Also "neutral" arthropods, like plankton feeders and detrivores, are important in controlling the pests as they stabilize the natural enemy populations by providing alternative food sources for the latter (Settle et al., 1996).Thus structurally complex landscapes lead to increased parasitism levels and decreased crop damage (Thies & Tscharntke, 1999, Pullaro et al., 2006), as concluded in a review landscape diversity effects on biological control (Tscharntke et al., 2008): "Complex landscapes characterized by highly connected crop-noncrop mosaics may be best for long-term conservation biological control and sustainable crop production".

IPM requires that the farmers, through observation and experimentation, learn about their agro-ecosystem so as to develop site specific technologies and practices (Pretty, 2008). The Farmer Field School (FFS) learning method, which focuses on the farmer as the key decision-maker in pest management and on the facilitation of a discovery-learning process using non-formal education methods (Williamson, 1998), has proven successful in situations of severe pest infestations and excessive synthetic pesticide use (see discussion below). FFS encompasses the following four principles: production of a healthy crop, conservation of natural enemies, performance of regular field observations and belief on the expertise of farmers in their own fields (Pontius et al., 2000). FFS is based on the idea that 'Learning is the process whereby knowledge is created through the transformation of experience' (Kolb, 1984: 38). Experiential learning is a process whereby we, based on the experience of a phenomenon, reflect and allocate meaning to that experience and develop knowledge from it. By experiencing the interactions of the agro-ecosystems and developing their analytical skills, farmers are empowered to realize which factors are within their own control (Fleischer et al., 1999).

According to Long (2001), knowledge is a cognitive and social construction constantly made by the experiences and discontinuities that emerge in the intersection between different actors' 'life worlds', defined as a person's life (or lived) experience, background and values which influence how the person sees the world (Schutz, 1962). Knowledge is a product of dialogue and negotiation, and includes transformation rather than transfer of meaning (Long, 2001). Although farmers may classify observable and culturally important insects better than many entomologists, they may not be aware of the parasitoids and insect pathogens in the agro-ecosystem. This was the case for Honduran smallholders, who distinguished a range of bees and wasps by their flight patterns, but were unaware of the existence of parasitic wasps and the carnivorous nature of wasp larvae (Bentley, 1992). Thus, for the learning and development of knowledge about pest management and the agro-ecosystem complexity, it is important to value both farmers' and scientists' knowledge and experiences. Participatory research approaches combining farmer knowledge and experience with research information could increase the ability to predict when synergies or negative interactions are likely to occur in the field and adjust management accordingly (NRC, 2010). As active farmer participation and public education are often a prerequisite for successful biological control (Williamson, 1998), the lack thereof may reduce the impact of introduced control agents, as was the case during the introduction of the parasitoid

Diadegma semiclausum Hellen (Hym., Ichneumonidae) in Southeast Asia. The parasitoid largely failed to control diamondback moth (*Plutella xylostella* L.) in brassicas in areas where farmers sprayed heavily with broad spectrum insecticides eliminating both native and introduced natural enemies (Waage, 1996, Gyawali, 1997).

IPM-FFS has been used for decades in Asia, where positive social changes (Pontius et al., 2000), have been documented along with reduced pesticide use, increased yield (Pretty & Waibel, 2005) and associated positive human and environmental health effects (e.g. Rola et al., 2001, Erbaugh et al., 2002, Godtland et al., 2004, Praneetvatakul & Waibel, 2006, WB, 2006) such as reduced pest resurgence (Matteson et al., 1994). FFS may provide an arena for shared learning between farmers, scientists and decision makers, with the emphasis on the farmers' experiential learning process, as in the Philippines, Pakistan and Honduras. In a vegetable IPM-FFS in the Philippines, farmers participated in releases of the diamondback moth parasitoid *Diadegma* sp. in their cabbage terraces and built wooden emergence boxes for the parasitized cocoons provided by the local university (ADB, 1996). From their observation of parasitized diamondback moth larvae and exercises demonstrating the effects of commonly used insecticides on the parasitoids, the farmers reduced their pesticide application by 80% and started asking the visiting agrochemical salesmen whether the products they sold were "Diadegma-friendly". Even the mayor of Atok town in the Cordillera region in the Philippines, got convinced about biological control to the extent that he banned all advertising of synthetic insecticides in his municipality (Cimatu, 1997). In Pakistan, FFS was undertaken to tackle the resurgence of the whitefly *Bemisia tabaci* (Gennadius Hom., Aleyrodidae), vectoring cotton leaf curl virus, and the increasing insecticide use in cotton (Poswal & Williamson, 1998). Whitefly may be kept in control by natural enemies, thus the whitefly outbreaks in Pakistan seemed to be a result of the elimination of the key natural enemies in cotton fields due to early and increased insecticide applications. The FFS participants learned about natural enemies and crop compensation by observing whitefly parasitization by Encarsia and Eretmocerus spp. (Hym., Aphelinidae), predation of jassids by mites, ants and spiders, and of whitefly by anthocorid and reduviid bugs, staphylinid beetles and spiders. Due to increased IPM knowledge the participants did not apply any insecticides on the IPM decision making plots the first 8-10 weeks after planting, thus allowing natural enemy populations to build up, and thereby reducing the total number of pesticide applications while yields increased. Having experimented with whitefly resurgence caused by the application of organophosphate, one FFS group demonstrated the impact of unnecessary pesticide applications to the Department of Agriculture officials, neighbouring farmers and local agrochemical salesmen.

In Honduras, the farmers learning about natural enemies and insect reproduction in the Natural Pest Control Course run by Zamorano (the Pan-American School of Agriculture), were able to enhance predation of pests in maize, potatoes and vegetables (Bentley et al., 1994, Rodríguez, 1993). As the farmers had learned the underlying principles of the agro-ecosystem, not merely specific techniques, they could also apply what they had learned to new situations (ibid.). These techniques adapted or invented by the farmers were tailored to their pest problems and resources in a way that standard 'recipes' could never be (ibid.). These results indicate why agricultural systems with high levels of social and human assets are more able to adapt to change and innovate in the face of uncertainty (Uphoff, 1998, Chambers et al., 1989, Bunch & Lopez, 1999, Olsson & Folke, 2001, Pretty & Ward, 2001). However, collective adoption of IPM techniques is vital, because the effect of IPM will be reduced if neighbouring farmers continue relying on chemicals for pest control killing beneficial parasites and predators, and exposing IPM farmers and local ecosystems to chemical spill overs (WB, 2006).

3. Effects of a vegetable IPM-FFS in Cotonou, Benin on pest management

In this section, the vegetable IPM-FFS by IITA-Cotonou will be discussed with emphasis on the extent to which the IPM-FFS training influenced the participants regarding their knowledge and use of IPM options including pesticides, their awareness of health hazards of synthetic pesticides and corresponding handling practices. Also the knowledge created through the interactions between the vegetable producers' and the scientists' 'life worlds' will be explored. The IPM-FFS project conducted two FFS sessions for farmers selected to participate in the Trainer Of Trainers (ToT) in 2003/04, covering the crops *Solanum macrocarpon* L. (Solanaceae) (a variety of the African eggplant, locally known as gboma), *Daucus carota* L. sativus Hayek (Apiaceae) (carrot), *Lactuca sativa* L. (Asteraceae) (lettuce) and *Brassica oleracea* L. capitata L. (Brassicaceae) (cabbage). To scale out the knowledge created in the ToT sessions, each ToT participant was to arrange horizontal sharing of knowledge and skills gained during the ToT sessions. The major factors limiting vegetable production in the urban and peri-urban areas of Benin are soil infertility, pests, weak irrigation infrastructure and poorly developed vegetable enterprises (James et al., 2006). Thus towards improved vegetable pest management, the IITA vegetable project found a strain of the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin (Deuteromycotina: Hyphomycetes) (isolate Bba5653) to be effective against the diamondback moth *Plutella xylostella* L., the most devastating pest of cabbage (Godonou et al., 2009a, Godonou et al., 2009b). As the microbial control agent is environmentally friendly and harmless to humans, it was part of the IPM options promoted through FFS training by the project along with botanical nematicides (Loumedjinon et al., 2009), as alternatives to synthetic pesticides.

The FFS training by the IITA vegetable IPM project created interfaces where the knowledge of the vegetable producers was challenged by the knowledge of other producers and scientists. Most of the vegetable producers believed that all arthropods in their fields would damage their crops, and therefore the project focused on distinguishing harmful insects from harmless and beneficial insects (e.g. *Cotesia plutellae* (Kurdjumov) (Hymenoptera: Braconidae), a parasitoid of *P. xylostella*, and the predator Exochomus troberti Mulsant (Coleoptera: Coccinellidae); (James et al., 2006). During the training, the participants were therefore exposed to IPM, beneficial organisms, plant health, agro-ecosystems and the concept of quality vegetables. Agro-ecosystem analysis (AESA) was used to assist participants to base their decisions on whether to apply synthetic pesticides on several criteria connected to observing the development of the plants, pests and diseases in vegetable plots. Vegetable producers were expected to change inappropriate IPM practices as a result of the training offered by the project.

3.1 Methods of data collection

The research was conducted in urban and peri-urban areas of Cotonou, department of Littoral, in 2006/07. In Benin, the law 1991/004 regulates packaging, labelling, transport, storage, usage and disposal of synthetic pesticides on the market, and the national plant protection service (Service de la Protection des Végétaux, SPV) is in charge of the quality control of synthetic pesticides and authorization of salesmen. The Centre d'Action Régional pour le Développement Rural (CADER) was in charge of the control of the use of synthetic pesticides, but it had closed down at the time of the survey. In this study, three vegetable gardens (Houeyiho, Office National d'Edition de Presse et d'Imprimerie (ONEPI) and Gbegamey), where vegetable IPM-FFS had been conducted, were compared with three vegetable gardens in Godomey where no FFS had been held (control group). The gardens where FFS had been held were selected on the basis of accessibility (short travel distance from Cotonou), that they were still in use as vegetable gardens and some of the crops covered in the project (carrot, lettuce, cabbage and gboma) were cultivated there. The control sites were the only vegetable gardens in Cotonou, which had not participated in the project. All the respondents produced vegetables for the market, and nearly all the land area in the gardens studied was used for vegetable production, while the respondents lived in other parts of or outside Cotonou. Each vegetable producer had his/her defined cropping area, consisting of several beds, with an average size of 7.2 m^2 each (James et al., 2006), but none of them owned the land they cultivated or had formal contracts with the landowner, thus their situation was very insecure (Zossou, 2004).

During the vegetable IPM-FFS, IPM options within the categories 'chemical, biological, mechanical and cultural' were taught. To distinguish how the different vegetable producers understood the concept of IPM, the number of IPM techniques (chemical, biological, mechanical and cultural) in which they mentioned IPM tools when answering the open-ended question, 'What does IPM mean?' was counted. It was also noticed whether the respondents only listed IPM options or explained a holistic approach using AESA. When IPM tools were mentioned within only one IPM approach, the respondents were considered as having a narrow understanding of the concept of IPM. When IPM tools were mentioned within all the four IPM approaches, their understanding of the concept of IPM was considered broad. While the 'concept of IPM' was based on how the respondents described IPM, the respondents' 'knowledge of IPM' was evaluated by the number of IPM techniques, in the four mentioned categories, in which they mentioned IPM tools as response to various questions during the interview. AESA was used in the IPM-FFS training to assist the farmers to take management decisions based on the conditions of their fields. The farmers observe the biotic and abiotic factors, analyse how these impact their crops and thereafter take proper management decisions based on the analysis (Pontius et al., 2000). To perform a sound AESA requires the farmers to have a good understanding of ecosystem interactions such as pest–predator relationships and the existence of beneficial insects. Insect zoos (enclosed pot with a plant, a pest and/or a beneficial insect) are often used to visualize the pest–predator relationships (Pontius et al., 2000).

A transect walk was done in all the vegetable gardens to get preliminary information about the area. Convenience sampling of the snowball type was used (Bryman, 2004), and the most available vegetable producers in the gardens were identified. Among these, the sample of producers was selected on the basis of gender, age, education, and economic and social status. The list of respondents was checked by the leadership of the community-based farmers union in Cotonou (Union Communale des Producteurs, UCP) to ensure that all socioeconomic categories were represented. From the IPM-FFS project area, 15 ToT participants, 9 FFS participants and 19 non-participants were selected. Twelve control respondents were selected from the area where no IPM-FFS had been conducted. Fifty-four semi-structured interviews with open-ended questions were carried out with the vegetable producers. The interviews focused on knowledge and use of IPM options, awareness of health hazards of synthetic pesticides, handling practices of synthetic pesticides, and knowledge and use of protection gear. Focus group interviews were held with the producers in the ToT, FFS and non-participant groups to collect data on synthetic and botanical pesticides, the IPM-FFS training and the production environment in the vegetable gardens. Female and male producers were interviewed separately for open discussions. Key informant interviews were held with an ambulant salesman of agro-chemical inputs; two elderly, experienced vegetable producers; and various NGO staff and government employees, as well as with project stakeholders from an NGO specialized in biological agriculture (Organisation Béninoise pour la Promotion de l'Agriculture Biologique), SPV, the national institute of agricultural research in Benin (Institut National de Recherche Agricole du Bénin), IITA in Benin and the UCP. Data was collected on pesticides (rules, regulations and sales) and on the IPM-FFS training (structure and curriculum). Triangulation and follow-up questions were used within the interviews to capture the respondents' real view. An interpreter was used for all the interviews with the vegetable producers so that the interviews were held in the common local language 'Fon' (spoken by most of the interviewed vegetable producers) or French.

As far as possible, the double difference model, comparing the differences in change over time between two populations, was used. The change in behaviour within the ToT and FFS groups was compared with the change in behaviour of the non-participants and control groups. A modified version of Mangan and Mangan's (Mangan & Mangan, 1998) model was used to assess producers' understanding of beneficial insects. The questions 'If you had the possibility would you like to kill all the insects in your field?' and 'Are there any insects that might be beneficial to have in your field (if yes give an example)?' were asked at different points during the interview. If the respondent did not want to kill all insects and could give examples of beneficial insects, she/he would be grouped as having a 'good concept' of beneficial insects.

3.2 Results and discussion

3.2.1 Increased IPM knowledge and plant health

All the ToT respondents, 56% of the FFS respondents, but only 16% of the non-participants were familiar with the term IPM. The ToT respondents had a broader understanding of the concept of IPM, but in general, most of the vegetable producers who were familiar with IPM had a narrow understanding of the concept of IPM (Fig. 1).

All the producers understood IPM as a separate management tool, but while most of them associated IPM with chemical control, the ToT and FFS respondents were more concerned about reducing the use of synthetic pesticides and using botanicals (such as neem, papaya, pepper, orange and cassava epidermis). 'Knowledge of IPM' was based on the IPM tools reported by the respondents during the interview. All the respondents had a broader 'knowledge of IPM' than 'concept of IPM', indicating that even though many vegetable producers were not familiar with the scientific term 'IPM', they knew about various pest management methods. A larger proportion of the ToT respondents (60%) had a good concept of beneficial insects than the FFS (22%), control (18%) and non-participant respondents (none). As the ToT participants were only shown pictures of the beneficial and harmful insects, but did not have any insect zoo, they lacked the experience of visually understanding pest–natural enemy relationships. As a consequence, many did not transform the information into reliable knowledge, as illustrated by a ToT participant: "*In the ToT I learned that beneficial insects eat the pest, but it is too risky to rely on it so I rather kill all the insects. I have to see how the beneficial insects behave in practice before I can trust that they won't damage my vegetables, but I don't have enough space to experiment with this*". In terms of AESA activities, the largest improvements in observing pests and crop interactions were among the ToT respondents (Fig. 2), who shifted from using preventive application to applications based on frequent observations of changes in crop, pest and natural enemy developments.

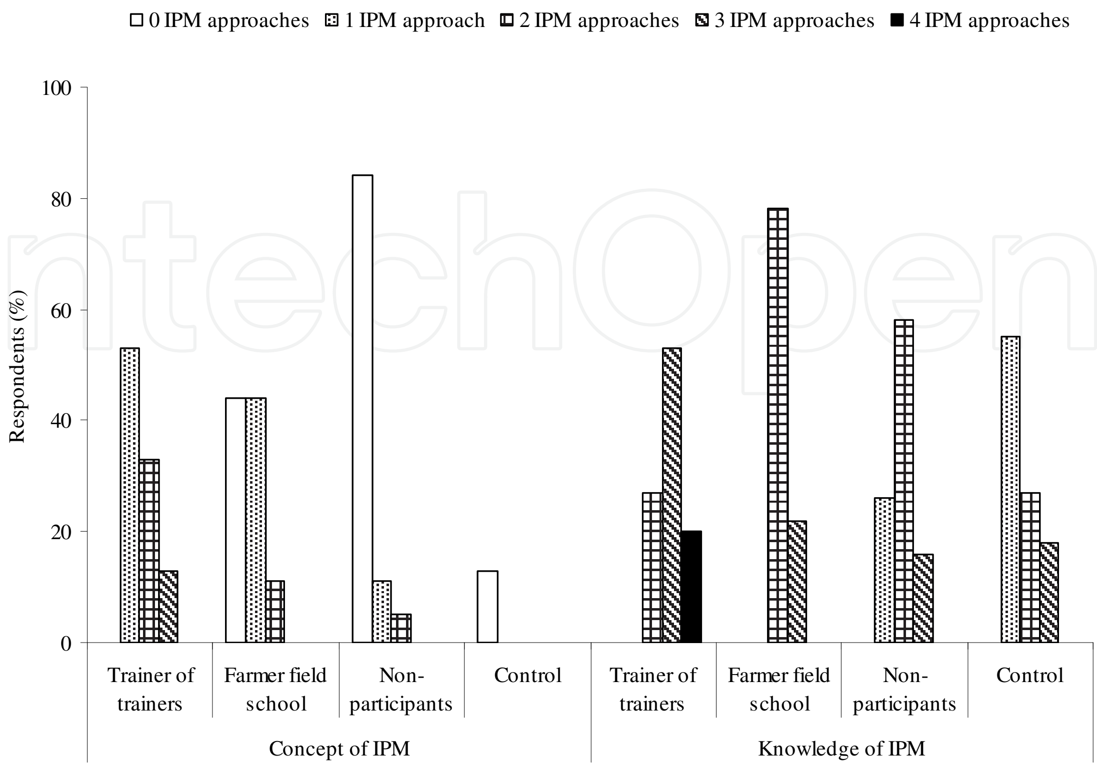

Fig. 1. Broadness of "Concept of IPM" and "Knowledge of IPM"

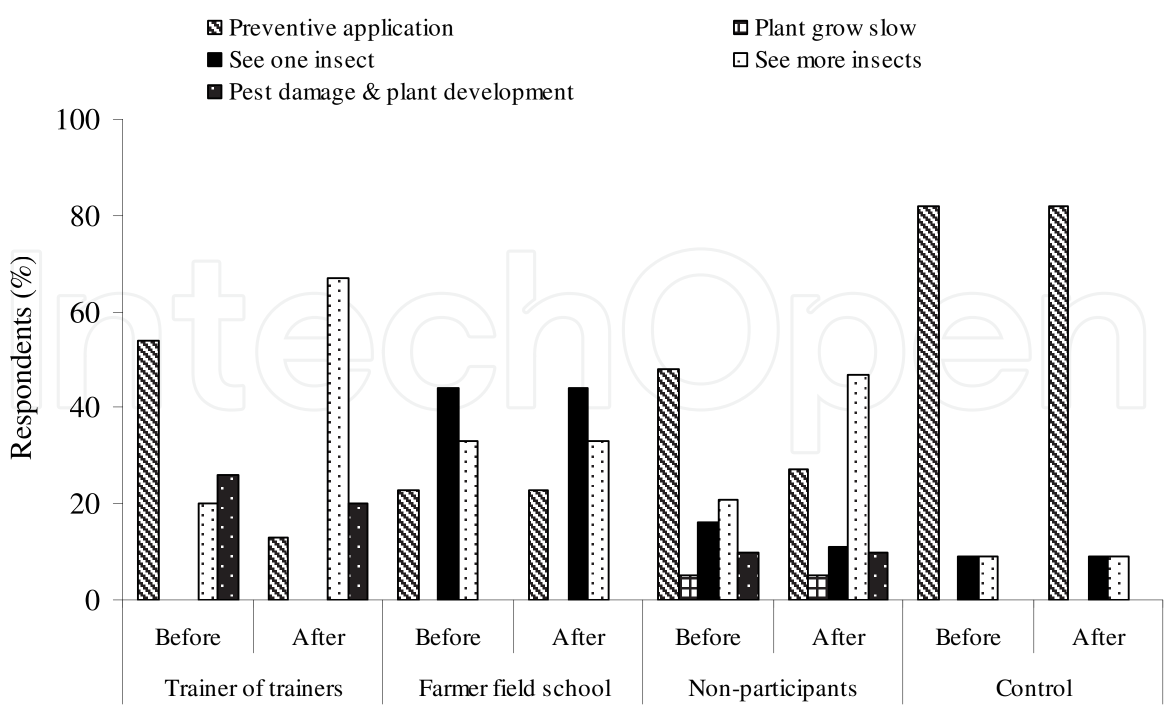

Fig. 2. Decision criteria used by vegetable producers to apply synthetic pesticides before and after the training

Sixty-seven percent of the FFS respondents said that the project had reinforced their knowledge to observe pests and crops, as told by a ToT participant: "*Now (after the Project) I greet my plants in morning and ask how they spent the night. If bad, I have to consider what to do*". Nevertheless, only one ToT respondent used agro-ecosystem analysis and based the management decisions on a holistic analysis of the field; the rest based their decisions on subjective assessment of increasing pest densities. The rate of calendar application was higher when the producers did not have a good understanding of beneficial insects, indicating that having a good understanding of beneficial insects may reduce the calendar application or vice versa. The largest change was among the ToT respondents (33%), shifting from consulting family and neighbours and not measuring at all, to reading the label and using information from the ToT/FFS training.

The term 'plant health', seemed to be a well-known term in the area, but how the respondents understood plant health differed. While the majority of the FFS (89%), non-participant (68%) and control respondents (63%) emphasized the use of synthetic pesticides to get healthy plants, the ToT respondents placed more importance on botanically and biologically based pesticides. Using organic matter to build the soil is important for plant health, and the ToT and FFS respondents were more aware of the importance of applying organic matter before sowing. However, the use of compost seemed to be dependent on the availability and price, as 82% of the respondents in Houeyiho used it, but nearly none of the respondents from the other areas used it. Also seed quality is important for plant health, and only ToT respondents (67%) knew how to use germination testing to check the seed quality, but even though all but one of them claimed to use it, no beds where germination testing was performed were observed during this study. The experiments in the project consisted of giving two beds different treatments and comparing the results. None of the respondents in the project experimented in this way as a result of the training. Forty-seven per cent of the ToT respondents and 22% of the FFS respondents, however, experimented in other ways after the ToT/FFS training, meaning that they tried out methods taught in the project such as the dose of synthetic pesticides, botanical pesticides, observing their fields, and organic and chemical fertilizers. While one respondent said: "*Cultivating vegetables is about experimenting*", others were more risk averse, and lack of time and land constraints were the most common reasons for not experimenting.

The respondents used 32 different types of synthetic pesticides (Fig. 3) and of these pesticides all the class 1b, but also some class II **(**Endosulfan and Fenpropathrin) and even class III pesticides (Orthene and Malathion**)** contained substances that are banned or severely restricted in the European Union (PANEurope, 2009), posing serious health concerns for the producers, consumers and the environment. Two respondents used endosulfan, which is prohibited in Benin and proposed by the POPs Review Committee to be eliminated from the global market (StockholmConvention, 2010).

ToT respondents were more often applying the correct pesticides against targeted pests than the other respondents. On the other hand, a large proportion of the control (82%), ToT (80%), FFS (44%) and non-participant respondents (42%) used 'cocktails', mixing up to four different pesticides. Two respondents illustrated the producers' difficult situation: *"I use Talstar against leaf miners and field crickets although I know it is not effective against those pests*" and "*I have no solution for the nematodes on my gboma. I think Kinikini would be effective, but I do not have money to buy it*". The use of cocktails of different pesticides made it difficult to evaluate the project's impact on frequency and quantity of pesticides used (Table 1).

The project recommended to use correct pesticides and to follow the prescriptions from the manufacturer, but as one respondent said: "*The pesticides they (the Project) recommended us to use are not available, so we have to use what is available*". Thus, due to unavailability and expensiveness, the majority of the producers sometimes or always bought synthetic pesticides in non-original packages not knowing what they were using. Even if the vegetable producers bought synthetic pesticides in the original packages, some respondents might be illiterate and the labels were often in foreign languages. Most of the respondents were very much aware of and respected the recommended pre-harvest interval. As indicated by one respondent, economic constraints may reduce the safety in pesticide applications: "*There is shortage of land and people need money so it is difficult to wait the recommended days before harvest*". On the other hand, the safety is also influenced by the individual and collective perception of ethics, as one respondent said: "*It has to be made socially unacceptable to not respect the pre-harvest interval*" and another respondent describing the changes due to increased awareness: *"Earlier some people sold the cucumber five days after spraying, but now everybody know they have to respect the harvest interval, so people will inform the buyer if the vegetable producer has sprayed too close to the harvest"*.

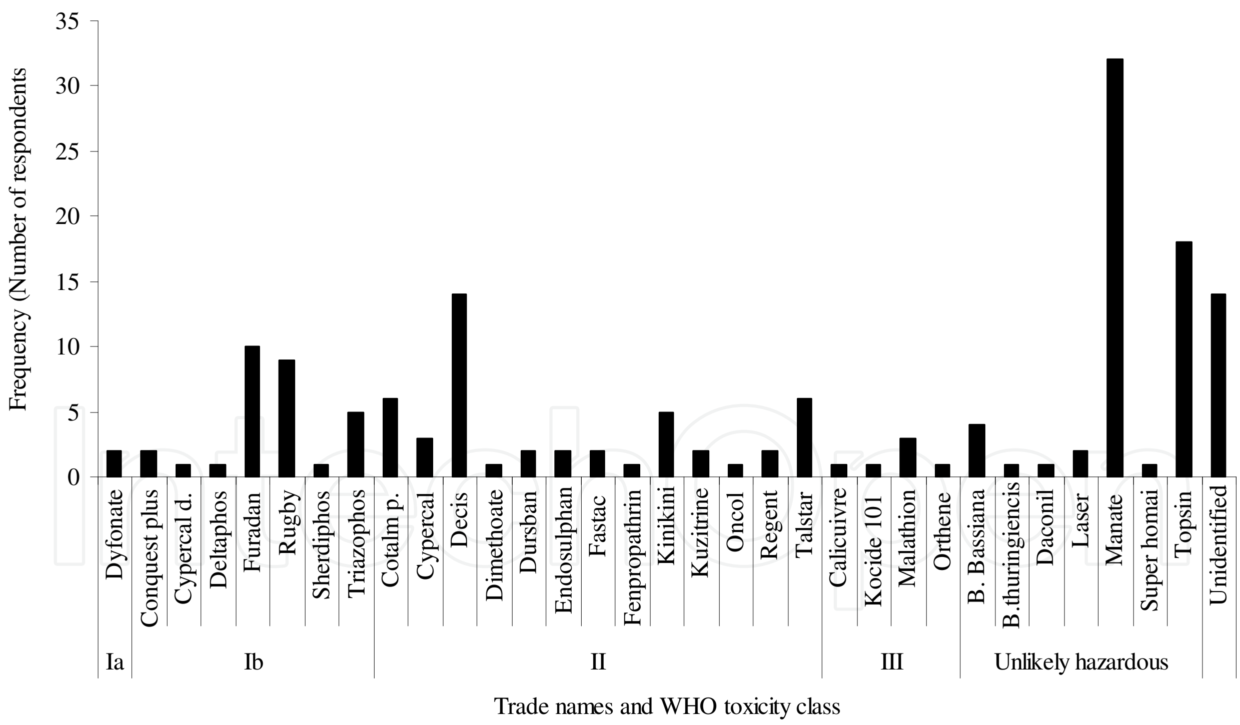

Fig. 3. Pesticides used by the respondents

Synthetic pesticides	Vegetable	ToT	FFS	NP	C	PB	ToT	FFS	NP	C	PB
		Frequency (times/crop season)					Quantity (l or g/ha)				
Decis (l)	Cabbage	27	-	33	10	7	19	-	138	46	31,9
	Gboma	2	2	3	3	5	2	2	-	6	7
	Lettuce	2	1	4	3	-	1	-	10	8	-
	Carrot	3	-	-	-	1	3	-	-	-	3,5
Talstar (l)	Cabbage	3	6	-	-	12	5	13	-	-	14,91
	Gboma	2	2	-	3	2	3	2	-	6	7
	Lettuce	2	1	4	3	2	1	-	10	8	7
	Carrot	1	-	-	-	-	3	-	-	-	-
Manate (g)	Cabbage	11	-	-	-	-	6	-	-	-	-
	Gboma	2	3	2	3	2	4	30	7	10	13,9
	Lettuce	2	2	2	3	2	3	3	4	13	19,9
	Carrot	-	-	-	-	-	-	-	-	-	-
Fenpropathrin (g)	Cabbage	-	-	18	-	-	-	-	9	-	-
	Gboma	-	-	-	-	-	-	-	-	-	-
	Lettuce	-	-	3	-	-	-	-	5	-	-
	Carrot	-	-	-	-	-	-	-	-	-	-
Endosulfan (l)	Cabbage	1	-	-	-	-	0,4	-	-	-	-
	Gboma	1	-	-	-	-	1	-	-	-	-
	Lettuce	1	2	-	-	-	1	6	-	-	-
	Carrot	1	-	-	-	-	3	-	-	-	-
Furadan (g)	Cabbage	-	-	-	-	-	-	-	-	-	-
	Gboma	-	1	-	-	3	-	46	-	-	13,9
	Lettuce	1	-	-	-	-	46	-	-	-	-
	Carrot	1	1	1	-	2	-	-	-	-	13,9

Table 1. Average frequency and quantity[1] of synthetic pesticides per growing season

[1]based on the quantity of concentrated synthetic pesticide, not quantity of active ingredients. NP = Non-participants, C = Control, PB = Project baseline data

The project emphasized the use of botanical pesticides as an alternative to synthetic pesticides. Forty-seven per cent of the ToT respondents, 26% of the non-participants, 22% of the FFS respondents and 9% of the control respondents said that they used neem, but during the time of this survey, no vegetable producers were observed preparing botanicals. The reason for not using neem extract was the time-consuming and labour intensive preparation as one needs large quantities of leaves or fruits. If they could buy neem extract commercially, many may use it because they had experience with it and appreciated that it was not harmful to the environment or to the individuals who applied it. In the project, knowledge about biological control was introduced. B. bassiana was used to control diamondback moth, and the vegetable producers could request it from IITA. Many of the vegetable producers were pleased with B. bassiana as it saved them money and labour, and their interest in the product was expressed by a ToT participant: "*When you use bassiana (B. bassiana) you are sure to succeed in growing cabbage. If I didn't have bassiana I would have stopped growing cabbage*". At the time, B. bassiana was given for free, but if the product is commercialized, the question remains whether the price will be competitive with respect to synthetic pesticides so the producers can afford it. However, increasing evidence of resistance in the diamondback moth may force producers to use alternatives or to abandon cabbage as a crop. Crop rotation was traditional knowledge used by all the producers, but they became more aware of its importance because of the ToT/FFS training. Even if some vegetable producers were not able to explain in scientific terms what was happening in their crops, they improved their practices based on experience, like one control respondent said: "*Normally you only have to apply pesticides three times, but if you grow the same type of vegetable two times after each other you need five pesticide applications*". All the ToT respondents, 94% of the non-participants, 78% of the FFS respondents and 73% of the control respondents practiced intercropping, but the main reasons for this practice were economic gains and land shortage. Also most of the respondents chose the planting time for economic motives considering market prices, while none considered plant health issues.

3.2.2 Awareness of health hazards from synthetic pesticides and proper handling practices

Awareness of negative effects of synthetic pesticides was quite high among the respondents, with the most known effect being hazards to the farmers' health as one respondent noted: "*It is not good to apply pesticides as it makes my eyes burn*". The control group had a more limited view of the negative effects of synthetic pesticides, and only mentioned human, consumer and farmer health, but not environmental and long term effects.

The overall awareness about protection while spraying synthetic pesticides was high (Fig. 4), as one respondent said: "*You should cover all the parts of your body. You may not feel anything today, but the pesticides will accumulate in your body and in some years cause heart problems and headache*", but the proportion actually using such equipment was low. Among the control respondents, 46% only wore shorts and T-shirts while spraying synthetic pesticides, but virtually none of the other respondents could show any of their protection gear. The most common reason for not using any protection device was expense, while another common reason in the tropics is the heat. The most common post-spray activity among the producers was to take a bath, done by most of the ToT respondents, while the control respondents were more likely to only wash their hands, legs and face. Most of the vegetable producers stored their synthetic pesticides buried in the vegetable field, hid it in the bushes nearby, or at home. Only the ToT respondents from ONEPI stored synthetic pesticides in a storage room, which could be locked, as they had a common storage room in the garden. Among the respondents buying original pesticide packages, all the FFS and control respondents, 62% of the non-participants and 22% of the ToT respondents sometimes stored the synthetic pesticides in empty soft drink bottles. When using pesticide bottles without labels or storing it in soft drink bottles, other people in the household may use the content in the belief that it is something else. Many threw the pesticide cans in the garbage or bushes where pesticide may leach out in the ground or accidents may happen if children find them. The most common way to apply pesticides was to use a spray sack, but 27% of the control respondents, mixed the synthetic pesticides with water in a bowl and used a bunch of grass to 'paint' the vegetables.

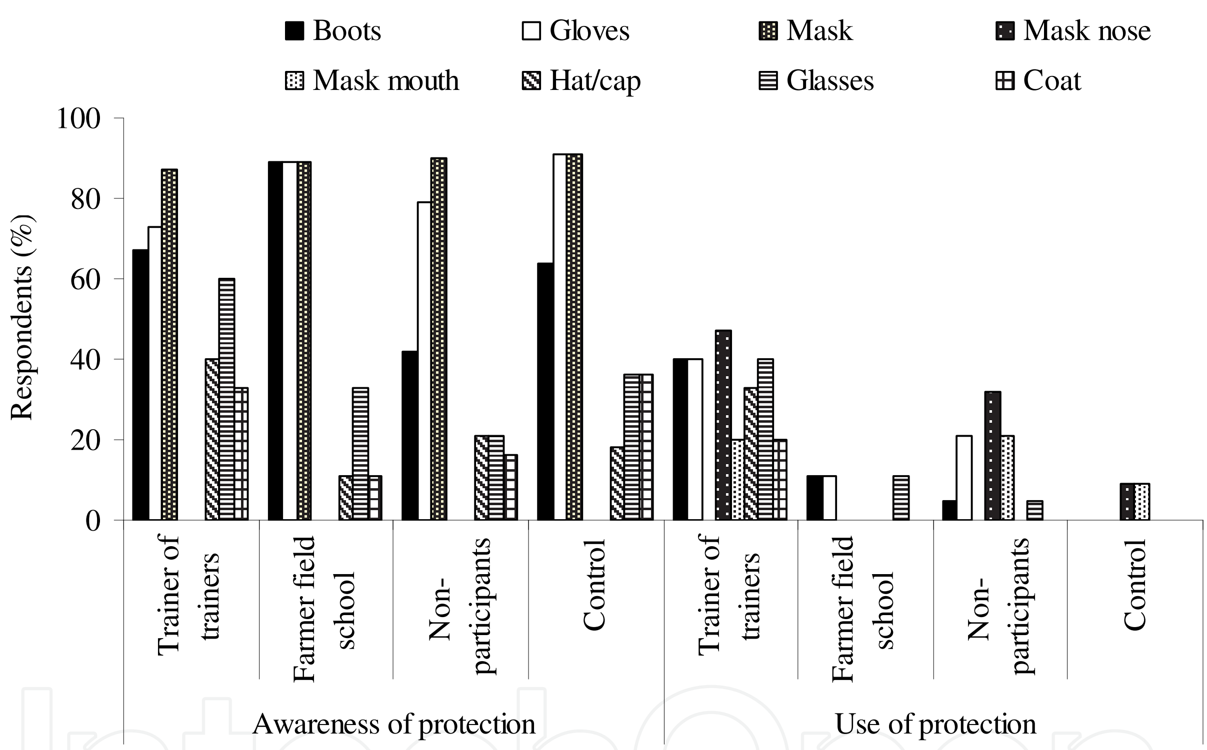

Fig. 4. Awareness and use of protection during application of synthetic pesticides

To scale out IPM knowledge and practices, the ToT participants were expected to carry out FFS sessions on all the four vegetables in the project. However, the FFS respondents' general complaints were that (1) the FFS sessions were often not conducted in both seasons and did not include all the four crops in the project and (2) the quality of the training was lower than that of the ToT sessions. The FFS sessions started the same season as the ToT sessions, thus not allowing the ToT respondents' time to develop their facilitation skills in IPM before commencing as trainers. Initially, the project only had IPM plots, but had no plots where the farmers' existing practice was demonstrated, which indicated a poor emphasis of the project on the vegetable producers' own experimentation and knowledge-creating processes.

4. Conclusion

The project increased the ToT participants' knowledge about IPM, reflected in their good concepts of beneficial insects, improved knowledge about plant health and pest management tools, improved ability to take management decisions based on pest occurrence in the field and increased experimentation with knowledge gained from the project. Increased knowledge and awareness about IPM may be one of the reasons for the participants' change in attitude towards synthetic pesticides. While some claimed having adopted biological IPM tools, the participants had not changed their practices significantly regarding the use of synthetic pesticides and cocktails, and most of the producers did not apply correct pesticides to the target pests. The FFS participants had gained considerably less knowledge than the ToT participants, which may be due to less intensive FFS sessions led by trainers with less developed facilitating skills. Experiential learning reflects and allocates meaning to that experience and develops knowledge from it. There were several examples of this issue in the project area, where vegetable producers, who did not know scientific terms such as IPM or nematodes, had nevertheless learned IPM practices based on experience. In the project, however, access to information about beneficial insects was mainly through theory, thus the participants did not experience what 'beneficial insect' meant in practice, and consequently did not transform this information into meaningful knowledge.

The practical use of concepts such as 'IPM' and 'agro-ecosystem' requires an understanding of complex interactions, which takes time to develop. Lack of monitoring of activities in their own fields is one reason why very few participants had a holistic and good understanding of those concepts. While it remains important to bring in scientific information to improve the vegetable producers' understanding, this information should be built on the participants' local knowledge to make sense to them and be relevant. The results show that the surveyed participants in the project did not adopt a complete package of IPM tools and concepts, but rather experimented with the new information and thereafter adapted parts of what they learned into their production systems. While Mancini (2006) found a strong correlation between knowledge level and the reduction in pesticide use among Indian farmers attending cotton IPM-FFS, also other studies show that farmers with a good understanding of how the field ecosystem works perform better crop management than those who get discrete and simplified pest management instructions (Mangan & Mangan, 1998, Price, 2001). However, in Benin, even the project participants with a good understanding of beneficial insects used superfluous pesticides, which might kill the beneficial insects. This shows that it requires more than a good understanding to change usual practices.

There are many factors in the vegetable producers' environment hindering them in using IPM and using synthetic pesticides more safely, including lack of ecological knowledge and access to product information, little availability of the right products and their relatively high cost. Many participants wished to produce good quality vegetables with safer use of synthetic pesticides. However, limited access to land and wish to make higher profits, were strong driving forces leading some vegetable producers to unsafe practices, such as not respecting the harvest interval and using forbidden synthetic pesticides. Also, normative considerations influence the vegetable producers' practices. As the laws on pesticide use are not enforced in Benin, these have limited impact on people's behaviour, but as seen from the survey, the awareness rising from various NGOs and research institutions has changed the vegetable producers' attitudes towards respecting the pre-harvest interval. Even more awareness rising is needed to change the producers' attitude towards synthetic pesticides and make dangerous practices unacceptable. Maybe even analysis of pesticide residues of products from individual beds to personalize the information could be an input that is an asset for producers to fully understand the problem of residues in the products.

The results indicate possible trade-offs between health and economic effects, with the latter weighing more heavily. The awareness of pesticide hazards and proper protection gear was generally high, and although many producers had experienced negative health effects of synthetic pesticides, most producers still did not use protection gear due to expense. The project did not have any impact on the safety in storage and handling of pesticides as the practices were rather influenced by what was more convenient for the vegetable producers.

This study shows that there is a need to focus more on the vegetable producers' own knowledge creation by emphasizing experiential learning, as well as to enable the producers to realize their role as potential knowledge generators (Simpson & Owens, 2002). This is in line with other studies emphasizing the importance of establishing a dynamic process where the participants take control over the experimentation (Braun et al., 2004) and on developing a 'learning style' (Pretty, 1995) that enables 'exploration, evaluation and adaptation of technological alternatives' (Lee, 2005 : 1332). Post-IPM-FFS activities would probably allow the participants in the Cotonou vegetable IPM-FFS to develop their ideas and concepts about IPM and agro-ecosystems as they practice these in their fields. There were many competent and knowledgeable vegetable producers in the studied areas concerned about the dangerous use of pesticides. In a follow-up of the IPM-FFS activities, these people could be the driving forces of promoting and implementing IPM in their communities. The general results from this study in Benin are in line with other reports (Maumbe et al., 2003, Mancini, 2006), concluding that for IPM to succeed as a proper and reliable plant protection strategy, not only is there a need to consider the educational component involving individual farmers or groups of farmers, but it is also necessary for all the stakeholders involved (farmers, extension, scientists, policy makers and NGOs) to understand the complex nature of IPM. In addition to the educational component, all other factors, such as the need for group versus individual action, farmer's indigenous knowledge, farmer's resource endowments, and last but not least the macroeconomic determinants, do play a significant role in establishing whether IPM can succeed or not. In light of findings from Benin and other IPM-FFS programs, further research is needed on how to facilitate the processes of knowledge creation between the farmers and scientists, and how to involve the ToT participants' in a way that they feel the commitment to continue the learning processes, to share knowledge with their farming communities and to initiate changes in pest management at the community level.

5. Acknowledgement

Thanks to all who contributed with their experience and knowledge to this research.

This chapter has drawn upon material from 'T. Lund, M.-G. Sæthre, I. Nyborg, O. Coulibaly and M. H. Rahman, "Farmer field school IPM impacts on urban and peri-urban vegetable producers in Cotonou, Benin", **International Journal of Tropical Insect Science**, 2 Volume 30 (1), pp 19-31, (2010) © ICIPE, Published by Cambridge University Press, reproduced with permission'.

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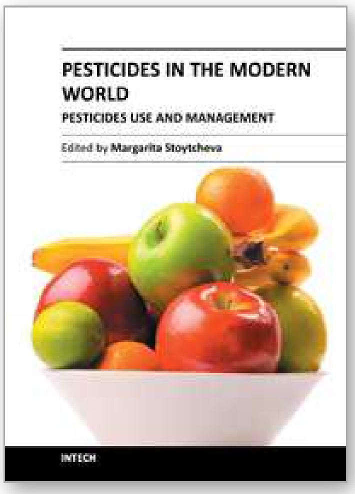

Pesticides in the Modern World - Pesticides Use and Management
Edited by Dr. Margarita Stoytcheva

ISBN 978-953-307-459-7
Hard cover, 520 pages
Publisher InTech
Published online 19, October, 2011
Published in print edition October, 2011

This book brings together issues on pesticides and biopesticides use with the related subjects of pesticides management and sustainable development. It contains 24 chapters organized in three sections. The first book section supplies an overview on the current use of pesticides, on the regulatory status, on the levels of contamination, on the pesticides management options, and on some techniques of pesticides application, reporting data collected from all over the world. Second section is devoted to the advances in the evolving field of biopesticides, providing actual information on the regulation of the plant protection products from natural origin in the European Union. It reports data associated with the application of neem pesticides, wood pyrolysis liquids and bacillus-based products. The third book section covers various aspects of pesticides management practices in concert with pesticides degradation and contaminated sites remediation technologies, supporting the environmental sustainability.