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Development of Integrated Pest Management system in Agricultural Production in Cameroon and the Central African Sub Region

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Abstract Due to the increasingly global concerns related to food self-sufficiency and food security in the developing countries, it seems imperative to critically appreciate the relevance and advantages of applying the "Integrated Pest Management (IPM)" concept in view of developing a long lasting and more competitive agricultural system in Cameroon and the Central African sub region. The goal of this reflection is to encourage stakeholders to contribute to IPM development. It presents the historical context and evolution of IPM, defines the concept, explains key components for the development of an IPM program, presents IPM techniques currently developed, and finally, proposes an inter-institutional collaboration scheme that integrates potentialities of different stakeholders while showing the advantages of developing and promoting this crop protection approach particularly in Cameroon and the Central African sub region. IPM is a multidisciplinary decision support system for the selection and use of pest control tactics, harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment. This approach coordinates the use of the biology of the pest/pathogen, environmental information and available technology to limit unacceptable levels of crop damages. The setting up of an IPM program is possible through six main stages with the following key components: (i) the decision making process including determination of the Economic Injury Level and Action Threshold through pests' surveillance and monitoring; (ii) collection and retention of approved, most appropriate and innovative control techniques; and (iii) devising management strategies against pesticide resistance. IPM concept is thus a strong advocacy tool for sustainable agriculture, serving as a framework for the development of research and application of a variety of control approaches, with benefits represented in terms of environmental protection and human security. These techniques are underutilized in Cameroon and the CEMAC sub-region, though the achievements gained through the few programs developed so far in this domain are significant and must be enhanced through further valorization of the rich flora of the sub-region by developing efficient biological alternatives to chemical pesticides.

Keywords: *Integrated pest management, IPM, pesticides, environment, Cameroon, Central Africa, sustainable agriculture, disease control, crop protection*

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1. Introduction

Agricultural pests and diseases are a major concern in Cameroon and the Central African sub region. With regards to the agricultural development policy in the Economic and Monetary Community of Central Africa (EMCCA) sub region, major strategic orientations have been defined in the vision of the sub-region within the framework of the Regional economic program (REP), to promote the development of the food and agricultural sector.

EMCCA (with French acronym CEMAC) is located in the Gulf of Guinea around the equator, and is made up of six (06) countries of the African continent namely Cameroon, Congo, Gabon, Equatorial Guinea, Central African Republic and Tchad. EMCCA has climatic conditions that are very favorable to agriculture, particularly in the South and coastal zones with a warm humid tropical climate (Cameroun, Congo, Gabon, Equatorial Guinea, and Central African Republic). It is one of the rare regions in the world where large surface areas of unused arable land still exist. The EMCCA sub region covers about 302 million hectares of land where arable land is estimated at 13,2 million hectares [1,2]. This region has four (04) climatic seasons in five (05) main agro-ecological zones: the Saharan zone, the sahelian zone, the soudano-sahelian to soudanian zone, the soudano-guinea to guinea zone, and the humid forest zone [2,3]. The population of EMCCA is estimated at over 42 million inhabitants [4], with 64.45% rural constituting the driving force of the sub regional agriculture [3,5,6]. The highly diversified agricultural potential of EMCCA can be grouped into three sectors notably (i) the subsistence food crops sector destined to local consumption (cassava, yams, *solanum* potatoes, plantains, maize, sorghum, millet, etc.); (ii) the cash crops sector essentially for exportation (coffee, cacao, rubber, banana, oil palm and oil seed production, cotton, tobacco, etc.), to which fruit trees (arboriculture) is today associated; and (iii) the market gardening and fodder legume sector (tomatoes, lettuce, onion, groundnuts, soya bean, etc.) [3,7,8]. Due to the importance of its natural resources, EMCCA projects to valorize this extremely rich agricultural potential. To attain this objective, EMCCA intends to focus on the modernization of agriculture by mechanization, the development of agricultural inputs (improved seeds, fertilizers, phytosanitary products, etc.), the support of producers and farmers' organizations and on the respect of technical itineraries [3].

Agriculture which plays a primary social role in the countries of the sub region remains the main economic sector of EMCCA, after the hydrocarbon sector. Here, agriculture employs about 64 % of the viable force and provides subsistence revenue for a greater part of rural populations. The agricultural sector contributes to about 25% of GNP of the sub region thanks to the export of its products to the international market [3]. Despite the annual exportation growth rate of about 3.3%, the part of this sector in the global value of exports is dropping over the years e.g. from 24.5% in 1995, the part of agricultural export got to 8.4 % by the end of 2005 [2,9]. Outstanding elements of this evolution are low agricultural productivity and a high concentration of extracting industries (petroleum and minerals). Moreover, the predominance of non tested cultural practices constitutes one of the main causes of low agricultural productivity in the EMCCA zone. Even though there exist large modern agricultural exploitations in Cameroon and in certain regions of Congo, the EMCCA region is characterized by traditional agricultural systems with a low rate of modernization [3,10].

With regards to food security, the under-nourished population of the sub region is about 30%. With reference to the FAO norm of 2400 kcal intake per person per day, EMCCA presents a nutritional deficit of about 206 kcal. Besides, the annual population growth rate (about 2.5%) of the sub region is greater than that of agricultural supply estimated at 2% [4,10], making most EMCCA countries to be net importers [2,10]. To guarantee production, the use of phytosanitary products is systematic in some cases, in a context where norms and good practices in the use of pesticides are unknown or less applied by the majority. This potentially compromises the future of the sector, particularly relative to the competitiveness of agricultural products from EMCCA [2,9].

In the EMCCA zone, Cameroon is the only country capable of appreciably supplying the local and external markets with most of the highly consumed and exported tropical products. In 2003, of the main agricultural products exported by EMCCA countries to the European Union, Cameroon alone contributed 89.47 % [2,3,10]. However, in spite of its great potential in the rural sector, Cameroon remains shock-sensitive to external pressures and continues to incur high expenses notably for the import of certain food products. To avert this situation, the Government of Cameroon is concerned with the modernization of production in order to assure local food security and self-sufficiency, to supply the processing industry, encourage local consumption and create a local market for the products of exportation crop sector and finally, to develop exports toward the international markets. The major projects for the modernization of the production sector are the improvement of the institutional framework and rural livelihoods, the sustainable management of natural resources in favor of a sustainable and rational development of the environment, the development of plant production by the promotion of medium and large exploitations, targeted and privileged state's support of farmers' organizations for access at reasonable prices to agricultural inputs, agricultural credits, and the promotion of Cameroonian agricultural products on the foreign markets as well as the development of related sectors. These actions towards development of plant production are aimed at improving the sanitary coverage of the farm, its regeneration and the extension of cultivated surface areas [11].

However, this strong wave of agricultural revolution both at the national and sub regional level carries along risks that threaten the health of the populations, the environment and the quality of agricultural products, if efficient strategies are not developed in parallel relative to food security, environmental protection and the development of sustainable agriculture by a better mastery of the constraints linked to the use of inputs like pesticides.

Meanwhile, the use of phytosanitary products is constantly on a rise worldwide. Their residues are found on treated fruits and vegetables and even in the interior air of houses. The persistence of pesticide residues in foods and in the environment results in the poisoning of about 3 million people worldwide each year, provoking chronic illnesses and deaths. According to the WHO, between 20.000 and 200.000 accidental deaths are caused by pesticides every year in the world, with a majority in the developing countries where about 30% of the commercialized pesticides are not in conformity with international quality norms [12]. Moreover, the contamination of ecosystems by these substances enhances the reduction of biodiversity [13]. The application of increasingly small quantities of these active substances imposes constraints concerning preparation and accessibility to adapted treatment materials by users especially in the developing countries [14]. In Cameroon, pesticides are the major input used in agricultural production. In the southern part of the country for instance, 51% of farms are sprayed with pesticides, although the users (peasants) don't have sufficient knowledge on the good agricultural practices concerning their use. At the level of these producers, the cost remains high, and these products are rare from time to time [15].

In addition, expired pesticides' management and the damaging effects of persistent chemical residues are also environmental concerns of global importance [7], as some modern chemicals are also broad spectrum and can cause problems if wrongly used. The synthetic pyrethroids used in pest control, for example, break down rapidly and have little residual effect in the tropics, but they are broad spectrum and repeated use can damage natural enemy populations [16]. With regards to the threat of an environmental disaster due to agricultural inputs (pesticides) and considering the importance of these chemical products in agricultural production, major stakeholders in the sector of chemical security management promote the use of less polluting and surer technologies [17]. In this light, there is the need for solutions that guarantee qualitative and quantitative improvement of agricultural production in EMCCA. According to FAO, the leading organization in matters of pesticides regulation and management notably the elimination of obsolete pesticide stocks in the developing countries [18], "integrated management is the most acceptable means of managing pesticides' threat in agriculture" [17].

The present reflection is an advocacy for the valorization and adoption of reasonable cultural practices through the promotion of "Integrated Pest Management" (IPM) in the protection of crops against pests and diseases in Cameroon and the Central Africa sub region. The goal is to encourage stakeholders to become interested, adopt and invest in the development of integrated crop protection in order to assure self-sufficiency and food security, and to supply the processing industry and the international market with better quality products.

2. The IPM Concept

2.1. Origin and Evolution of the IPM Concept

Before World War II and the generalized use of organo-synthetic chemical products in agriculture, problems of pests had generally been managed using cultural practices and information on the life cycles and biology of the pests. The development and use of the organo-synthetic chemical products have oriented the management of pests toward the adoption of chemical control. By the end of the 1950s and at the beginning of the 1960s, the increased level of chemical resistance of insect populations and the damages caused by pesticides on non targeted organisms became a major preoccupation. This led entomologists to develop and encourage the concept of integrated control. In fact, the "Integrated Control" concept was created by a group of entomologists directed by V. Stern at the end of the 1950s in the University of California, Riverside. This concept was based on the selective use of chemical products in the protection system, excluding the role of natural enemies found in the ecosystem. Contrary to entomology, phytopathology since its beginnings, undertakes control against plant pests in association (or while integrating) various traditional control strategies, notably crop rotation, the use of seeds exempt of pathogenic organisms and genetic resistance of hosts. Thus, the term Integrated Pest (population) Management (IPM), initially confined to entomology and in pests' control became current in the literature of phytopathologists since the year 1975 [19] and began to arouse interest. From the original "Integrated Control" concept in the 1959s was born the modern "Integrated Pest Management" (IPM) concept that has today evolved to "Integrated Crop Management, Resource Management, and Sustainable Agriculture" in a globalizing systemic approach that goes beyond the examination of pests, to lay emphasis also on the examination of the other components of the ecosystem [20].

Much of the current understanding of the principles of IPM developed from work on tropical crops. As early as 1962, it was recognized that insecticides were causing pest attacks in oil palms, by upsetting the ecological balance between the pest and its natural enemies. In "Pests of oil palms in Malaysia and their control" [16], the authors enunciated the principles of what was then known as integrated pest control, explaining the reasons for pest outbreaks, methods of monitoring pest populations and ways of controlling pests without disruption of the natural balance in the agro-ecosystem.

2.2. Definitions of the IPM Concept

IPM is a multidisciplinary decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment [21,22]. In his article titled "Integrated pest management: Historical Perspectives and Contemporary Developments", Kogan [21] detailed the components of the acronym "IPM" as considered at the time of its inception in the scientific and public nomenclature as follows: "Integration", which translates the harmonious use of several methods to control the impact of one or several pests; "Pests" which corresponds to all organisms that are harmful to humans, including animals, pathogens and weeds, invertebrates and vertebrates; "Management" which refers to a set of rules or decisions based on ecological principles, as well as economic and social considerations.

With regard to pest in particular, Smith and Reynolds [16] proposed an ecologically based classification according to which:

(i) Key pests are perennially occurring, and would cause severe damage in the absence of control measures. These are pests for which the limitation by natural enemies is generally inadequate.

(ii) Occasional pests may cause sporadic economic damage, if the usually good environmental control, including biological control, is disrupted.

(iii) Induced or potential pests cause no significant damage under current conditions, but have the potential to do so if environmental controls were disrupted by changes in agricultural practice (usually the application of an insecticide).

In summary, the following definition can thus be given to the "Integrated Pest Management (IPM)" concept in agriculture: IPM is a protective system against the diseases and pests of crops that, taking into account the direct relation between the dynamics of the population of the parasite and the environment, uses all techniques and suitable methods in the most possible compatible manner to maintain the size of the populations at a level below the threshold of important economic damages [23]. IPM thus coordinates the use of the biology of the pest or the pathogen, environmental information and the available technology to limit unacceptable levels of damages due to pests, by the most economic means, while presenting the least possible risk on people, goods, resources and the environment.

3. Development of an IPM Program

3.1. Main Stages in the Development of an IPM Program

It is recommended that wherever possible, growers should use integrated pest management (IPM) systems which involve the encouragement of biological control of pests, the adoption of agronomic methods that minimize the risk of pest outbreaks and, if pesticide application is unavoidable, the use of selective chemicals and application methods with minimal side-effects [16].

The setting up of an integrated control program is possible through the following stages [20]:

- The mastery of the pest or pathogen through studies on their biology as well as problems that they cause on the plants in a given ecosystem;
- The development of a control or monitoring system for the problems identified;
- The mastery of the crop through studies on its biology, production and economic aspects;
- The development of a decision making procedure in view of initiating the control measures by a description of the critical situation of the farm or a schematic description of the state of damages not to be attained in the corresponding farm situation;
- The selection and assessment of all available control methods for the case at hand (cultural practices, biological, chemical, etc.) and the identification of the point or the stage of the cycle at which the pest or pathogen is more sensitive to the tested control measures;
- The exploitation of results obtained to formulate a control strategy against the targeted pest or pathogen in the form of a global program.

3.2. Key Components in the Development of an IPM Program

3.2.1. The Decision Making Process

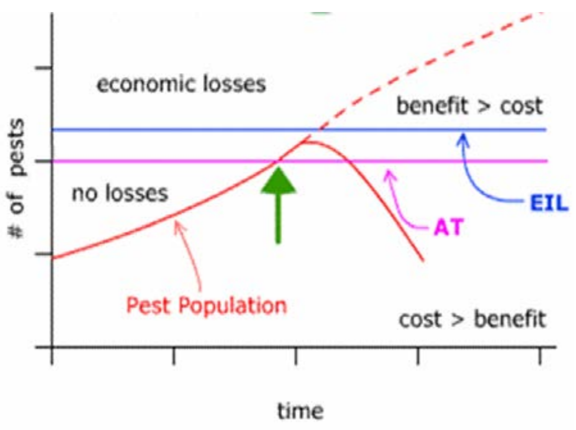

Figure 1. Components of the decision making process in integrated control (Source [24])

The Economic Injury Level (EIL) and Action threshold (AT) are two important notions of an integrated control program (Figure 1) [24]. The EIL is the boundary value of the size of the pest population or of the economically acceptable level of the disease. It corresponds to the population size beyond which the crop begins to incur damages of economic importance. Meanwhile, the AT corresponds to the population size or the level of infestation of the crop cultures that justifies a treatment to avoid that the parasite population reach a size susceptible to cause economic damages. In an integrated protection program, the action threshold is a tool of the decision making process that precedes all control actions.

3.2.1.1. Pests Surveillance and Monitoring Techniques

As an example in the entomological approach of control against aerial pests, pheromones and colored traps with or without food decoys are used to attract, capture and evaluate the variations of the pest populations in the field. In the case of terrestrial pests, soils are sampled and suitable traps like the pitfall trap are used.

3.2.1.2. Case Study of the Decision Making Process

In practice, if responses are to be based on pest numbers, then a regular monitoring system must be in place. Pest numbers may be counted directly, or an assessment of damage may be made. Most systems involve at least two stages: a superficial inspection for signs of pest incidence known as the 'detection' stage, and a more detailed assessment where such signs are found, the 'enumeration' stage. Mariau cit. [16], gave a more general review of census systems in various parts of the world, together with a list of advice notes on pests published in *Oléagineux* between 1967 and 1994.

The action level for a pest may depend on the weather e.g. the leaf miner *Coelaenomenodera lameensis* multiplies more slowly during drought, so the action level can be higher. *C. lameensis*, is a serious pest of the oil palm in West and Central Africa. This beetle is found on oil palms and, to a lesser extent, on coconut and *Borassus* palms throughout West and Central Africa. Serious attacks, causing widespread defoliation, have been reported from Ghana, Benin, the western part of Nigeria, Ivory Coast and West Cameroon. As an illustration of the decision making procedure towards control of this pest, a census method was developed in the Ivory Coast by Mariau and Bescombes, which involves counting of adults and larvae on a leaf in the lower part of the canopy, with small and large larvae, nymphs and adults being recorded separately. The palms selected for counting are changed at each census round. Counting is done every 3 months when the number of larvae is below 10 and of adults below 1; monthly when the numbers are 10-20 and 1-3, and weekly if more than 20 and 3, respectively. When the latter stage is reached treatment is considered necessary [16].

In sum, the decision making process in the development of an IPM program is subtended by a prior evaluation of the crop and pest in view of determining the pest infestation threshold necessary for a strategic intervention.

3.2.2. Collection of Approved Control Techniques

After the decision making stage, the following techniques may be assessed and used in the second phase of the IPM program development.

3.2.2.1. Some integrated control methods used in crop protection

There exists a variety of techniques currently utilized in integrated crop protection. They include host resistance, modified agronomic practices, reduced pesticide use, biorationales, predators, insect pathogenic bacteria, insect pathogenic fungi, insect pathogenic nematodes, parasitoids, etc.

Control by agronomic practices includes crop rotation, slash and burn, deep ploughing, the alternation of irrigation techniques in the farms, etc.

Meanwhile Genetic control involves the use of resistant varieties, the use of transgenic plants (e.g. tobacco and maize have been transformed genetically in order to produce the toxins of *Bacillus thuringiensis* in the control against the Lepidoptera). Moreover, the transgenic cultivars with insecticidal properties have been developed against the caterpillars or larvae of some pest.

In addition, Physical (and Chemical) barriers such as nets are used around the farm plots as screens preventing the invasion of pests. Attractive colors or insecticides are sometimes associated. Insect traps with colorful adhesive bands are also used as means of control in "in door" farms.

On its part, Biological control uses nematodes, bacteria and entomopathogenic fungi, and parasitoids. Biological control also involves the use of insect predators as well as the Sterile Insect Technique (IST) which is a system of lethal dominance or a form of "birth limitation" that causes the production of sterile eggs by the wild females, leading to reduction of the population of insects following the spray of sterile insects produced industrially. Bio-insecticides (preparations of parasitic fungi or insect viruses, or *Bacillus thuringiensis*) can also be effective [16,25,26,27].

Symbiotic control is a newly introduced technique based on the improvement of beneficial insects, the induction of cytoplasmic incompatibility, and the modification of the symbions.

Chemical control is the last recourse that should be used in case of emergency. Selectivity can be achieved not only by choice of chemical, but also by the timing and method of application. Knowledge of the pest life cycle may allow application to be timed to a stage when the maximum kill can be achieved, while sparing natural enemies. For example, with the oil palm pest, *C. lameensis*, spraying may be most effective against adults; larvae in galleries within the leaf lamina are protected from contact pesticides [16]. Efforts are thus needed for: a maximal reduction of the use of pesticides, innovations in the pesticides application techniques, and for bio-rational pesticide development.

From the evaluation of all available techniques in the second phase of IPM program development, the most appropriate and innovative techniques are retained for the case at hand. Studies could equally be undertaken in order to devise possible combinations of efficient and compatible techniques to constitute the integrated pest management program.

3.2.3. Devising Management Strategies Against Pesticides Resistance

In the next step of IPM program development, programs to manage the resistance of pests against pesticides (integrated resistance management (IPM-IRM programs) are developed to guarantee the durability of integrated protection programs being developed. These strategies aim: to reduce the use of pesticides as much as possible by integrated control techniques; delaying resistance development by rotating different active ingredient groups and restricting their use to certain periods of the year; and not using mixtures of insecticides for controlling pests (e.g. *Bacillus thuringiensis* and synthetic pyrethroids) [28]; to coordinate the use of insecticides; and to assure the monitoring and assessment of the resistance. Using broad spectrum pesticides in a random manner may cause pests, diseases and weeds to rapidly develop resistance.

3.3. Overview of IPMs in the Cameroonian and EMCCA Context

IPM practitioners in Cameroon have over time used indigenous knowledge systems in the control of pests. Since the 1990s initiatives towards the development of integrated crops protection against pests and diseases are a major preoccupation of agricultural R&D institutions in Cameroon and the EMCCA sub-region.

At the level of research, IITA constantly initiates IPM programs against pests and diseases, particularly against ACMV, through the development of resistant varieties, biocontrol with natural enemies of pathogenic organisms like those of white fly (*Bemisia tabaci*), introduction of the parasitoïd *Fopuis arisans* against the fruit fly (*Bactrocera invadens*), the improvement of the habitat of the predators of mites (*Typhlodromalus aripo*), the use of entomopathogenic fungi against aphids, initiation of biological control methods against cocao pests, cassava mealybug, and banana weavils [29]. Worth noting are the numerous endeavors undertaken by the Institute of Agricultural Research for Development (IRAD) of Cameroon in collaboration with partners such as CIRAD on the use of *Trichoderma spp.* in the biological control of cacao brown rot caused by *Phytophtora infestans*, as well as the use of endophytes in crops protection [30,31,32]. Moreover, research efforts in universities and other institutions have led to studies on biopesticides of plant origin such as tropical plant extracts (neem plant, *Thevethia peruviana*), crop pests' biodiversity and ecology, etc. [33,34,35,36,37] as well as the use of essential oils as bio-pesticides [38,39,40,41].

From a field extension perspective, indigenous knowledge systems on plant protection have been exploited by the Ecologically Sustainable Cassava Plant Protection (ESCaPP) program which sponsored a nation-wide extensive diagnostic survey of cassava production constraints in Cameroon in 1994. These knowledge systems include seed treatment, treatment on the field during crop growth, or during post-harvest. Farmers and extension workers select their planting materials from disease-free plants and equally use host-plant resistance.

During the life cycle of the crop, rodents are a problem. Thus fences may be built to protect the crop, or chemical baits may be used where there are no cattle. Cultural practices are used in pest control directly when the pest is physically removed from the farm or indirectly by creating unfavorable conditions for the pest to thrive in. The direct methods include hand picking, weeding, trapping, hunting, and fencing. Indirect methods involve many agronomic practices like intercropping, rotations, timing of planting and harvesting, and good seedbed preparation. These practices which vary with the culture of the people have been handed down from generation to generation without proper documentation [42]. Other traditional products used by the farmers are based on Indian hemp (*Cannabis sativa*) against food crop pests. Moreover, plants as *Guibourtia tessmannii* (local name: *Essingang*) and *Erythrophleum ivorense* (local name: *Elon*) are regularly used in some villages to deal with witches (*Essingang*) and as poison (*Elon*). Farmers also test the effectiveness of such local products against cocoa pests. The tree extracts are used either alone or mixed with the pesticides previously used to control cocoa pests [15].

In most cases of application of modern control techniques against crop pest in Cameroon and the sub-region, the use of resistant varieties coupled with spraying of pesticides is the most used approach. However, few integrated pest management programs are beginning to be implemented in the sub-region with diverse outputs. During the last two decades, PRASAC started an insecticide promotion program named "*Lutte Étagée Ciblée*" (LEC) in Cameroon, Tchad and Central African Republic in partnership with cotton production industries in these countries. In fact, LEC, a protection program against cotton pests, was developed [43] and promoted for the first time in the northern region of Cameroon by SODECOTON at the beginning of the 1990s. It is based on two protection "stairs" (étages) or phases: i) the first phase consists in following the classical treatment calendar i.e. spaying insecticide every 14 days from the date of floral budding, but the difference here is that the insecticide dose usually applied is reduced by half; ii) the second phase consists of adding the half dose of the first phase thereby applying a full dose of treatment when observations the day before treatment reveal that the pests population has exceeded the economic injury levels. In a nut's shell, the LEC technique helps to reduce by half the usual doses of insecticides applied, if damages do not exceed the economic injury thresholds. Good performance of the technique was observed in Tchad and Central African Republic in experimental conditions. However, the LEC technique has been progressively abandoned due to poor pests' counting conditions, little economic gain brought about by the technique, bottlenecks in the management of the technique, and the coexistence of several crop protection programmes in the same environment [43,44].

More recently, the Sustainable Tree Crops Program (STCP) has enhanced the promotion of integrated control techniques at the level of peasant farmers against cocoa pests based on Farmer Field School (FFS) Training on Integrated Pest Management in the humid forest region of Cameroon. This concept which reflects a paradigm shift in extension work has been promoted in recent years by a number of development agencies, including the World Bank as a more effective approach to extend science-based knowledge and practices. It is a participatory approach of diffusing new science based knowledge and information to farmers [15,45,46]. This STCP tests the FFS in integrated pest management through pilot projects in Cameroon, utilizing participatory methods to help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions [45]. This FFS has provided farmers with new skills and knowledge on cocoa ICPM, especially on pruning of cocoa trees, shade management, phyto-sanitary harvesting, spraying methods and fermentation. It encourages experimentation, observation and decision-making. The STCP cocoa ICPM-FFS concentrates more on cultural practices (e.g. pruning, shade management, phytosanitary harvesting and disease management). Knowledge transmitted to farmers by the STCP program was related to four broad areas covered in FFS: rational pesticide use for pest and disease management and improved farmers' knowledge of diseases and pests, cacao physiology, and post-harvest operations. Learning occurs through three types of activities: i) Discovery learning exercises which allows farmers to develop an understanding of concepts and principles related to the topic as well as skills or practices, while field activities focus solely on teaching skills or practices; ii) Through conducting agro-ecosystem analysis (AESA), FFS participants learn how to make close observations on farm conditions and to analyze the interactions between the cocoa trees and other biotic and abiotic factors coexisting in the field; iii) The group learning process, and specifically group dynamic exercises, are designed to increase farmers' communication skills, self-confidence and encourage team building [46]. Meanwhile, cooperation between research and development institutions has led IITA and IRAD Cameroun, within the framework of an initiative supported by FIDA and SDC, to take actions towards reducing African root and tuber bugs on farms.

Some IPM techniques developed in Cameroon are summarized in Table I. They are an illustration that IPM techniques are currently applied in Cameroun and the ECCMA sub-regional agricultural systems. However, given the necessary investment on research and extension activities, these techniques are underutilized. But the achievements gained through the few programs developed so far in this domain are significant and must be enhanced in view of extending this to the entire sub regional community. In addition, the rich flora of the sub-region must be further valorized in the development of effective and efficient biological alternatives of chemical pesticides.

The delay noted in the popularization of the IPMs has revealed many limitations for which lessons should be drawn to consider new strategic development and promotion of integrated approaches in order to promote the effective takeoff of the agro-industry sector in the EMCCA region. Amongst the limitations are:

- the lack of a strategy and structure for the coordination of actions taken by the various players thereby reducing the effectiveness of ongoing initiatives;
- the lack of infrastructure and appropriate equipment especially in the application of cutting edge techniques of the domain;
- the lack of staff capacity-building programs within organizations;
- lack of knowledge of the current regulations in the field of pesticides use in crop protection and in experimentation settings;
- low development of the applications of the IPMs in the fight against crop diseases, weeds, and nematodes;

- ignorance and the underutilization of the principles of integrated control in production systems;
- the absence of well framed permanent communication mechanisms and information exchange between the players in this field.

Table 1. Some IPM techniques developed in Cameroon

	Techniques used	**Host Plants tested**	**Pest/disease controlled**	**Authors and year**
Chemical protection	Pesticides spray (Insecticides and fungicide)	Vegetable (Amaranth, Cabbage, Sweet and hot pepper, Onion, Eggplant, Tomato, Okra)		Abang et al., 2013
	Spray of pesticides	Sorghum	Stem borer (*Sesamia cretica*)	Aboubakary et al., 2008
	Spray with fungicide (Ridomil)	Cacao	Black spot disease	Sonwa et al. 2008 ; Deberdt et al., 2008
	Biopesticides (botanical protection**)**			
	Neem extract	Sorghum	Stem borer (*Sesamia cretica*)	Aboubakary et al., 2008
	Essential oils from *Xylopia aethiopica* (Dunal), *Annona senegalensis* Pers., *Hyptis spicigera* L. and *Lippia rugosa* L. of Cameroon	*Zea mais*	Maize weevil **:** *Sitophilus zeamais* Motsch.	Ngamo et al., 2007 Noudjou et al., 2007
	Crude extract of *Thevetia peruviana*	Groundnut (*Arachis hypogaea* L.)	Leaf spot disease of groundnut caused by *Cercospora sp.*	Ambang et al., 2007
	Seeds extract of *Thevetia peruviana*	Cacao	Black pod disease caused by *Phytophthora megakarya*	Ambang et al., 2010
Cultural techniques	**Rational pesticide use** (spraying based on observation, choosing the correct sprayer nozzle, correct use and maintenance of sprayers, protection during spraying and pesticide selectivity) **Cultural practices:** pruning, shade management, phytosanitary harvesting and disease management	Cocoa (*Theobroma cacao)*	Black pod disease and mirid	Soniia, 2007
Biological control	Spray of *Trichoderma asperellum* suspension	Cacao	Black pod disease of cacao	Tondje et al., 2007
	Essential oil of *Xylopia aethiopica* Dunal, *Lippia rugosa* and *Vepris heterophylla*	Cereal	Weevils *Sitophilus zeamais* and *S. oryzae* *Tribolium castaneum*	Ngamo et al., 2007
	Essential Oils from *Cymbopogon citratus*, *Ocimum gratissimum* and *Thymus vulgaris* as Seed Treatments	Rice (*Oryza sativa* L.)	Seed-borne Fungi: *Alternaria padwickii*, *Bipolaris oryzae* and *Fusarium moniliforme*	Nguefack et al., 2008
Combination of IPM approach	**Monitoring + chemical control:** Observation of the variation of pests abundance in the farm Pesticide spray: Cypercal P720 EC (120 + 600 g/l of cyperméthrine + profenofos)	Cotton (*gossypium*)	Chenilles carpophages (*Helicoverpa armigera*, *Diparopsis watersi & Earias* spp.)	Nibouche et al., 2003 Deguine et al., 1993
	Chemical control + biological control: Spray with fungicide Ridomil Spray with suppression of *Trichoderma asperellum*	Cacao	Black pod disease (*Phytophthora megakarya*)	Deberdt et al., 2008
	Chemical control + biological control: Spray of fungicides *Trichoderma asperellum* oil formulations	Cacao	Black pod disease (*Phytophthora megakarya*)	Mbarga et al., 2012
Indigenous knowledge systems on plant protection				
Chemical control	**Biopesticides** Tree extracts from *Cannabis sativa*, *Guibourtia tessmannii* and *Erythrophleum ivorense* used either alone or mixed with the pesticides	Cocoa	Cocoa and food crop pests : Capsids *Phytophtora* Black pod disease	Sonwa et al., 2002
	Chemical baits	Cassava and others	Crop pests, rodents, cattle	Ambe Tumanteh and E. T. Awah
Cultural practices	**Direct**: hand picking, weeding, trapping, hunting, and fencing; **Indirect**: intercropping, rotation, timing of planting and harvesting, and good seedbed preparation **Hosts plant resistance**	Cassava and others	Crop pests, rodents, cattle	Ambe Tumanteh and E. T. Awah

4. Conclusion and Perspectives

The Integrated Pest Management concept (IPM) is a strong advocacy tool for sustainable agriculture, mindful of the opportunities that it represents as a framework for the development of agricultural research and the application of a variety of control approaches among which are techniques accessible to producers in the developing countries, and given the benefits that this approach represents in terms of environmental protection and human security. The selection and use of control methods, sampling or monitoring procedures, and economic injury levels are the tactical components of the IPM strategy [21]. The important aspects of an Integrated Pest Management system can be summarized as follows [16]:

- Knowledge of the life cycle and ecology of the pest, and of its natural enemies, is required.
- A monitoring or census system to ensure early detection of outbreaks should be in place, so that control measures can be planned, and applied at the most appropriate time.
- Economic damage and action thresholds should be established, so that control measures are taken only when necessary, giving the natural balance a chance to be re-established.
- Control measures must be selective, so that swift re-establishment of the natural balance is promoted.

IPM approach deserves particular attention in the agricultural development programs (notably in crop protection) which are underway in Cameroon and the Central Africa sub region. The approach offers a vast field of Research and Development activities to Research Institutions and Universities for them to find potent and sustainable solutions to crop protection problems that affect agriculture, while improving on the quality of the agricultural products of the sub region.

To guarantee the quality of agricultural products and food security, countries of the EMCCA sub region need to put in place visions and strategies aimed at promoting the quality of these products in view of mastering better management of the sector, particularly through the use of IPMs. In this perspective it appears worthwhile to propose an inter-institutional collaboration scheme that will integrate the potentialities of different stakeholders notably:

- research structures (Institutes and Universities) could lay the fundamental bases for the development of integrated control programs against the phytosanitary problems of interest, develop strategies and establish integrated protection programs of national and sub regional scale;
- field extension structures like the States, Projects, and Specialized Organizations could implement the laid down strategies.
- producers could then apply the control strategies in the agricultural exploitations.

Such a scheme has the potential of driving the development of integrated protection in view of a qualitative and quantitative improvement of agricultural production and hence the competitiveness of the agricultural products of Cameroon and the sub region in the local and international markets. This will help to master the risks related to agricultural modernization, to avoid the threat of environmental disasters due to the abusive use of pesticides and finally to assure a sustainable agricultural development at the national and sub regional levels.

To achieve this goal, there is need to reinforce sub regional structures in charge of phytosanitary protection in order to render them operational and more efficient, with the goal of respecting international norms, scrupulously applying phytosanitary measures and ensuring quality control [2,10]. In this context, the main actors of the sub region, notably CPAC, competent authorities and research and development institutions have to play the central role in the sensitization and coordination of producers in view of promoting IPM technologies with particular attention on rural populations which are largely less educated.

Abbreviations

IPM:	Integrated Pest Management
EMCCA:	Economic and Monetary Community of Central Africa
REP:	Regional Economic Program
C.E.M.A.C.:	Communauté Economique et Monétaire d'Afrique Centrale
GNP:	Gross National Product
WHO:	World Health Organization
IPM:	Integrated Pest Management
EIL:	Economic Injury Level
AT:	Action threshold
IST:	Insect Sterile Technique
IRM:	Integrated Resistance Management
ACMV:	African Cassava Mosaic Virus
ESCaPP:	Ecologically Sustainable Cassava Plant Protection
PRASAC:	Programme Régional de Recherche Appliquée au Développement des Systèmes Agricoles d'Afrique Centrale
LEC:	Lutte Etagée Ciblée
SODECOTON:	Société de Développement du Coton
STCP:	Sustainable Tree Crops Program
FFS:	Farmer Field School
IITA:	International Institute of Tropical Agriculture
IRAD:	Institut de Recherche Agricole pour le Développement
FIDA:	Fonds International pour le Développement Agricole
SDC:	Agence Suisse pour le Développement et Coopération
EMCCA:	Economic and Monetary Community of Central Africa
REP:	Regional Economic Program
UNESCO:	United Nations Educational Scientific and Cultural Association
PER-CEMAC:	Programme Economique Régional-CEMAC
CPAC:	Comité inter-états des pesticides d'Afrique Centrale
DSCE:	Document de Stratégies de Croissance et de l'Emploi
DRIAAF:	Direction Régionale et Interdépartementale de l'Alimentation

	de l'Agriculture et de la Forêt d'Ile de France
FAO:	Food and Agricultural Organization
EIL:	Economic Injury Level
AT:	Action threshold
IRM:	Integrated resistance management
PRASAC:	Programme Régional de Recherche Appliquée au Développement des Systèmes Agricoles d'Afrique Centrale

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