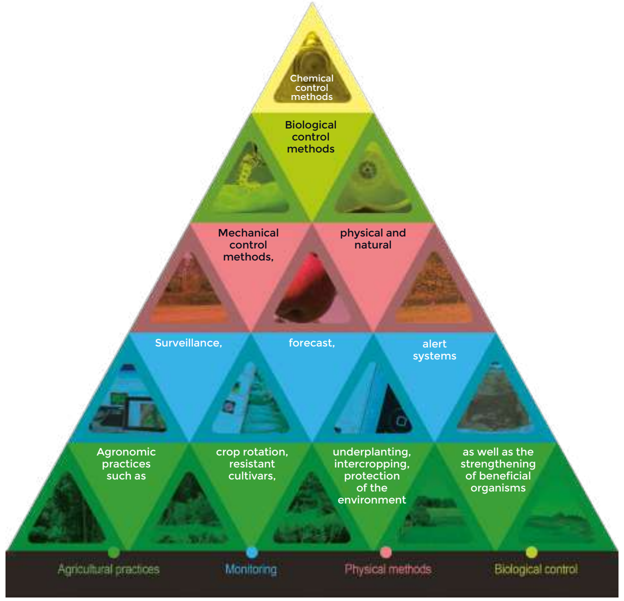
MODULE 3: PROMOTION OF PESTICIDE ALTERNATIVES

EDUCATIONAL OBJECTIVE:

Know how to identify insects and diseases, better prevent their development and propose alternatives to pesticides that are less dangerous to humans and the environment.

The objective of this module is to develop biological control and a better knowledge of pests and auxiliaries in order to implement a crop protection strategy without pesticides. With respect to global principles, the pyramid below presents the different tools and methods that can be implemented by farmers to allow them to avoid the use of pesticides as much as possible. To obtain the healthiest possible crops, basic principles of agroecology lie at the base, including a variety of practices, cultivation systems and landscapes. Then come the observations, which are crucial for making the right diagnosis and choosing the right strategy.
This is followed by the choices made by farmers in the management of their crops: in the event of crop infestation by pests or weeds, integrated pest management methods are mentioned first and, at the top, chemical pesticides should only be used as a last resort[22]:



[22] Extract from the IPM guide "Integrated Pest Management, working with nature" IOBC, PAN Europe, IBMA Global - Free to download in English and French. Here is a link to the French version: https://www.pan-europe.info/sites/pan-europe.info/files/public/resources/other/La%20Lutte%20Inte%CC%81gre%CC%81e%20Travailler%20avec%20LA%20Nature.pdf.

TOPIC 1:

Identify specific examples of how pesticides have negatively impacted biodiversity in cultivated and uncultivated areas.

1. the destruction of beneficial trees in plots due to the use of total weedkillers;

2. the impossibility of combining cereal crops with legumes, okra, bissap, etc., for those who use cereal-specific herbicides;

3. the negative effects of cotton insecticides (including organophosphates and neonicotinoids) on bees and other beneficial insects;

4. in connection with the previous point, the development of "white flies" (= Bémisia Tabaci or whitefly), particularly in vegetable crops are close to cotton fields and in those where vegetable crops in the rainy season follow those farmed in the dry and cold seasons;

5. in several cotton-growing areas of Africa, okra, cowpea or guinea sorrel (whose fruits and/or leaves are consumed by humans) are sometimes combined with cotton, which is treated five times during its cycle, with insecticides not registered for food crops. There, it is human biodiversity that is directly threatened!

6. cross-reactions of cotton insecticides on malaria-carrying anopheles have been observed by some researchers (source: communication from JF Gueguen, INRAE et IRD).

Presentation of the association Bee Friendly's role

It is sometimes difficult for farmers to clearly understand how their practices impact biodiversity. An ideal way to overcome this would, if possible, be to get in touch with local beekeepers. Through observation of their bees, they have detailed knowledge of melliferous and nectariferous resources available throughout the year and also the state of environmental pollution linked to the use of pesticides. In Europe, this is the work of the Bee Friendly association.

This association restores the link between beekeepers and farmers in order to build a new agricultural model. Whether wild or domestic, the protection of bees is at the heart of practices that promote agro-ecological transitions involving the elimination of the most toxic pesticides for bees, the development of biodiversity to feed pollinators and constructive exchanges between beekeepers and farmers. It is also known that crop auxiliaries also feed on nectar: "what is good for the bees is good for the farmer". (https://www.certifiedbeefriendly.org/).

TOPIC 2:

Together with participants, identify the crop pests causing the problems specified in the surveys conducted in Module 1 on village lands as well as beneficial organisms and endogenous solutions that could help resolve these problems.

For example, the task is to:
1. Identify the insect pests that attack crops: their life cycle, from egg/larva to adult stage, the different plants or places in which they live, reproduce and feed throughout their life, know their date of emergence and end of cycle (see box below).

How can knowledge about insect pests and auxiliaries be developed?

The basic principle is observation. The greater the number of observations, the more precise and reproducible the diagnosis will be.

1) Data collection
The easiest way is to take a picture of the insect, with a smartphone for example. The location/plant on which it is observed, the date and time taken as well as weather details *(temperature, dry or wet weather, after a rain or not) should be systematically noted).*

As practiced by RECA Niger and two GRET teams in Kifa and Kaédi in Mauritania, a WhatsApp group can be created and shared with volunteer technicians and farmers. Sub-groups for individual crops can also be created. In this way, participants will be able to publish all the photos taken of insects found on a specific crop and exchange them with specialists and researchers.

In order to observe insects closely and identify them, it may make sense to capture them and keep them in an insect tube or a plastic bottle for example.

An **insect net** can be used for more detailed observation. This method always makes sense because the quantity and quality of the insects present on a crop can be shown (generally, our eyes tend to see much less than what is present).

This method also allows for comparison of different insect populations based on the time of capture, weather conditions, or a plant's development cycle.

2) Identifying insects
The internet can be used to identify the main crop pests and crop auxiliaries. The insects observed must first be organized in two categories: crop auxiliaries and pests. For crop auxiliaries, the main question should be: how do I encourage them at the right time on my crop? For pests, the main question is: which insect feeds on the pest, its eggs or larvae?

In this case, the first step is to identify the name of the insect. A Google search for "[crop] insect" may be helpful while accessing the image search to identify the insect spotted or captured. There are also applications on smartphones *(to be tested, however, depending on the country)* such as "Agrobase", "les insectes ravageurs" (insect pests), neither of which are free of charge, however, there are others that are freely available.

Some Facebook pages also show insects or farmers and technicians can post their pictures and ask what the name of the insect is *(example: RECA Phyto Facebook page)*, "Which insect is this?" "Insectes de France - identification, discussion" *(despite its name, there are sometimes photos of insects from all over the world)* or in English "Ask an Entomologist".

There are also websites that can be easily found via an internet search, for example, "cotton insect pests". Some databases can be consulted, such as the ephytia database of Inrae (France), the ecophytopic website, etc. There are also specialized books on crop insects: "Insectes et acariens des cultures maraichères en milieu tropical humide" (Vegetable crop insects and mites in the humid tropics) P. Rickewaert and B.Rhuno, 2017.

Once the insect has been identified and its scientific name has been found, internet research allows us to understand its way of life, its diet, its breeding grounds and, finally, the methods to be implemented to promote or limit it.

In addition, many countries have entomology experts. Contacting them always proves to be informative and is recommended, especially if they agree to collaborate with the WhatsApp® groups that have been set up and, if necessary, to come to the farmers' fields.

2. Know the insects and birds present in the villages, which are recognized as beneficial for crops (= crop auxiliaries). Many insects contribute to the pollination of crops and therefore to the quantity and quality of the harvest. As we will see later, other beneficial insects kill one pest or the other (pest/auxiliary pair).
To increase the population of an auxiliary insect, one must be familiar with its life cycle, the plants required for its growth and reproduction.

The importance of pollination for adequate crop quality: the case of strawberries

a lack of insect pollination can lead to yield and quality losses in agricultural crops, e.g. deformed fruits in the case of strawberries

Source: https://www.agroscope.admin.ch/agroscope/fr/home/themes/environnement-ressources/biodiversite-paysage/compensation-ecologique-fonctions/abeilles-sauvages-pollinisation/cultures-entomophiles-souffrent-elles-uisse-deficit-pollinisation.html

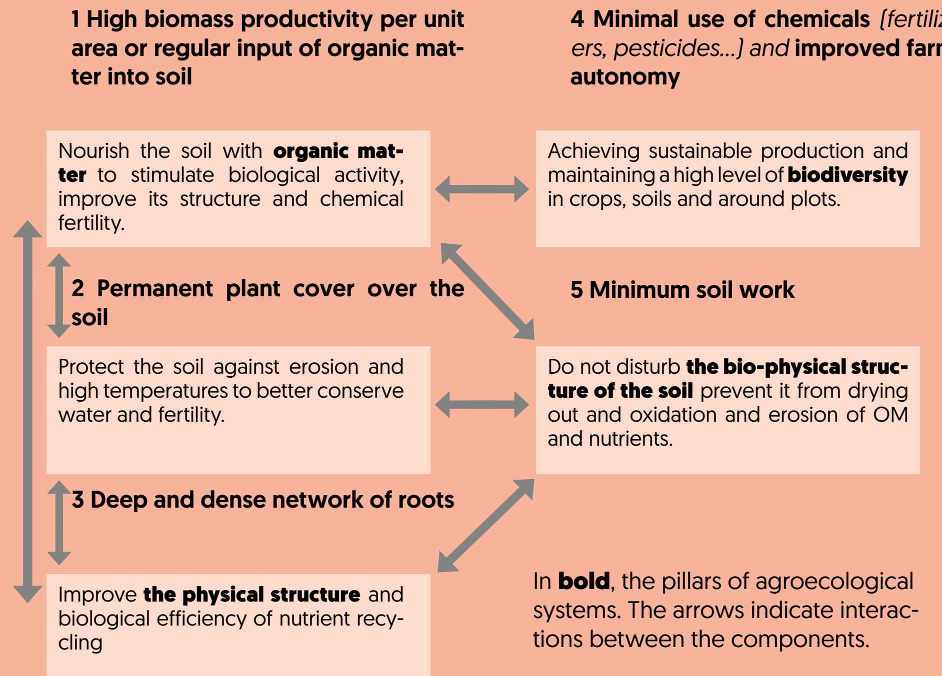
TOPIC 3:

Identify and implement ecological transitions that minimize as much as possible the use of pesticides. To achieve this goal, and based as much as possible on the participants' practices, identify possible options for crop rotations, selection of crop species and varieties of livestock animal species, choice of sewing methods and mechanical weeding tools.

Include the reduction of pesticide use in more global agro-ecological transitions

Reducing the use of pesticides is an essential part of transitions towards more sustainable forms of agriculture. To achieve this objective at the level of a plot, herd, farm, or even territory, a global approach is advisable as is a combination of knowledge and practical skills from agronomy, ecology, but also from socio-economic sciences such as geography, land management methods, etc. The following box explains a number of key principles of agroecology.

Source: books on **the functioning of agroecological systems**
M. Altieri and de S. Gliessman [23]



In **bold**, the pillars of agroecological systems. The arrows indicate interactions between the components.

[23] S. Gliessman, 1998: "Agroécologie, the ecology of sustainable food system" - Miguel Altieri – 2002: *"agroecology: the science of natural resource management for poor farmers in marginal environments"*

More specifically, how to better manage diseases and pests and reduce pesticides?

Basic rules:

• Know the **cycles of the aggressors** (the time when attacks are frequent as well as their technical and economic implications), and if possible those of the auxiliary insects. In order to progressively develop biological control through conservation (see Topic 4), it is important to cultivate knowledge of the interactions between pests and their auxiliaries, and of the treatment practices and landscape components (grass belts, trees and shrubs, hedges, etc.) that influence the presence of auxiliaries.

• to **recognize the arrival of insects of concern** in the plots but also **the presence of certain beneficial** insects, use a few panels coated with glue, ideally several colors (each type of insect has its preferred color) and yellow bowls containing water and a small amount of odorless dishwashing liquid, which prevents the insects from floating (https://www.terresinovia.fr/-/la-cuvette-jaune-le-piege-incontournable-pour-detecter-l-arrivee-des-ravageurs-du-colza). NB: At this point, the task is not to attempt to capture as many insects as possible, but simply to identify their presence in the plots.

• **Evaluate the risks at the level of the crops and herds** (treat once a certain threshold is reached to avoid ineffective preventive treatments).

• Know the **primary methods for controlling the identified pests.**

• Benefit **from data collected by a network of farmers and technicians** (e.g. bulletin de santé du végétal (plant health bulletin)) in France, targeted pest management for cotton in some countries, network of agricultural advisors and farmers' observers trained by RECA Niger).

• In order to ensure collective control of certain pests, **encourage grouped treatments** involving farmers from the same area.

Preliminary and preventive measures to reduce the risks of attack (diseases, pests):

• Avoid **monocultures** (importance of long rotations of different species).

• For a given crop, **identify the plots where risks of diseases or pests are high.**

• Give preference to **varieties that are tolerant** to the diseases or pests identified as significant.

• Cultivate **combinations of varieties** or **mixtures of species** with varying tolerances to major diseases or pests. Attacks are reduced with certain annual crop combinations, certain tree-crop combinations *(cf. advantages of agroforestry)*; l**however, the opposite can occur** and not all species combinations or ecological infrastructures around the plots are beneficial [24]! **In these areas, it is necessary to capitalize on references and share technical, environmental and economic results with farmers.**

[24] In areas where seed-eating birds have a significant impact, farmers are averse to the presence of trees in or around the fields because they serve as nesting spots or perches for these birds.

• **Do not sow contaminated seeds or plants** (frequent problem with certain viruses, fungus spores, insect larvae or eggs). This involves taking precautions when selecting seeds in the field, storing them or buying them from outside sources.

• **Disinfect** the storage places of crops and seeds with natural, low-toxicity products (use of ash and certain plants).

• **Treat seeds with methods that are not hazardous to human health** *(avoid hazardous fungicides and insecticides).* Low-impact treatments: very mild sun exposure on tarpaulin laid out on the ground; ashes or low toxicity plants; very fine sand mixed with seeds, which significantly limits the movement of insects; the mixture is later sifted at the time of sowing *(see Module I, Topic 4 of this guide Alternative farmer practices identified by AVSF in 2014 in Northern Togo and, Topic 5, NPLCs);*freezer where possible and seed quantities are reduced...

• **To conserve cowpea [25] attacked by multiple insects including bruchids, use triple-bottom bags** called PICS bags (this synthetic material bag lined with two plastic bags can be used for long-term storage of cowpeas without the need for chemicals; see https://reca-niger.org/spip.php?rubrique9).

• Preserve as much as possible **the beneficial insects** (e.g. bees for pollination) and other beneficial animals or insects that already live in or around the plots *(thanks to hedges, [26], grass belts, etc...).* In this context, avoid the drift of insecticide treatments along plot edges; avoid treatments when insects are feeding; opt for treatment times at the end of the day.

• **Firmly oppose the use of neonicotinoid insecticides[27] on the land!** They destroy beneficial insects. Indeed, scientists have observed the decline of wild and domestic bees in areas where such active ingredients are used (https://www.lemonde.fr/afrique/article/2019/11/15/l-afrique-risque-de-devenir-un-deversoir-pour-des-pesticides-bannis-d-europe_6019278_3212.html). Like bees, most crop auxiliaries feed on nectar. Therefore, protecting the food resources of the bees also helps to promote crop auxiliaries.

• **Foster shelter and breeding areas for birds and beneficial insects,** such as in trees or dead branches left on the ground in an uncultivated area of a vegetable plot (cf.https://www.eco-conso.be/fr/content/8-idees-toutes-simples-pour-favoriser-la-biodiversite-au-jardin). But be careful, managing nature is no simple task and false solutions should be avoided (https://www.terrenature.ch/favoriser-la-faune-pres-de-chez-soi-les-fausses-bonnes-idees-a-eviter/).

[25] Statement by Patrick Delmas, RECA Niger: "Too many prohibited products are used in Niger to protect cowpeas. For instance, to conserve the seeds, the producers spray them with Dichlorvos *(= an organophosphate insecticide banned in the EU since 2007, banned by the CSP but authorized in Nigeria...).* This is probably the most widely used insecticide in Niger. It is responsible for deaths and multiple intoxications".
[26] For several reasons, the introduction of hedges can be complicated or even prohibited in many regions in Africa (e.g., refusal of landowners who fear that their land rights will be challenged or refusal of herders who do not wish to limit the free movement of their livestock).
[27] There are currently 7 active ingredients from the neonicotinoid family on the market: acetamiprid, clothianidin, imidacloprid, thiacloprid, thiamethoxam, nitenpyram and dinotefuran, and two other compounds recognized as having identical modes of action: sulfoxaflor and flupyradifurone (cf. *Appendix 7).*

• Remove from the plot (or shred) crop residues that may contaminate subsequent crops (e.g., eggs, larvae of certain butterflies and other insects that survive on these residues).

• Cultivate trap plants in or around the plot that repel or attract certain pests.

Preliminary measures to reduce the pressure of "weeds" that penalize crops:

• **Rotations of sufficient length with alternating species.**

• **Weeding** before, during and after cultivation **to control the most troublesome weeds** before they set seed. Not easy, however, with rhizome-growing perennial weeds or with striga...

• **Stale seed bed** (where possible...).

• **Crop combinations that can limit the development of certain weeds** (e.g. combination of corn, sorghum or millet and creeping cowpea varieties that cover the soil relatively quickly).

To illustrate some of the approaches described above, Appendix 9 describes a combination of practices used on a crop farm in Anjou (Western France).

Other practices *(unfortunately not all of them are applicable to all farmers and in all pedoclimatic contexts):*

• **Collective control of certain pests** (e.g. monkeys, warthogs, etc. in Africa; wild boars, musk-rats and coypu in France).

• In arboriculture, **nets for protection** against birds and certain insects ...

• **Fruit bagging** (banana bunches) or grafting.

• **Decoys** *(cf. role of scarecrows but also of scaring hawks and owls).*

• **Various biological control methods described under Topic 4 below, taking care to prioritize those that are accessible and not too costly for the farmers.**

• **Use of old mosquito nets as veils.**

Use of veils in a Mauritanian market garden (Photo V. Beauval)

These veils can protect the crops from birds, flies, whiteflies (= Bemisia tabaci), etc...
This solution is appropriate at certain times of the crop and pest cycle, however, several crop species require pollinators which the veils may impede.

TOPIC 4:

Know and promote biological control methods that can be used in African or other tropical farmers' agriculture (11 examples).

The main objective of biological control is to reduce the use of chemical pesticides by promoting natural mechanisms and interactions between species.

As illustrated in box [28] below,**biological control is based on managing the balance of pest populations rather than eradicating them.**

The different types of biological control

• Biological control by **introducing a predator, parasite or pathogen.**
• Biological control **in the form of "flooding"** with **massive and seasonal releases of crop auxiliaries.**
• Microbiological **control** *(e.g. Bacillus thuringiensis producing a toxin).*
• **"Autocidal"** control through the introduction of sterilized males.
• **Biological control** through conservation to protect, maintain and increase populations of crop auxiliaries.

One tends to distinguish as follows *(source: Ecophyto site of the French Ministry of Agriculture):*

• the **target** (of the control) is an **undesired organism, pest** of a cultivated plant, livestock parasite, etc.;

• the **control agent** *(or auxiliary)* is a different organism, most often **a parasite or predator of the former**, which kills it in a more or less short term by feeding on it or by limiting its development. The crop auxiliaries that we try to use are most often insects, entomophagous mites. They also include bacteria, viruses and fungi that cause certain diseases in insect pests. In some cases, larger animals are also used, such as fish to control mosquitoes or ducks to control snails in rice fields.

The table below lists some examples of targets and predators of these targets.

[28] Source: "La lutte biologique classique: exemples et leçons de la Polynésie française" (traditional biological control: examples and lessons from French Polynesia). JY Meyer, J Grandgirard. The entire slide show is important in order to be aware of the successes and failures of biological control. Available on the internet: http://eee.mnhn.fr/wp-content/uploads/sites/9/2016/01/lutte_biologique_Polynesie_francaise.pdf.

Target = predator	Damage caused by the predator	Auxiliary = predator of the target	Action of the auxiliary
Aphid	Sap collection; virus transmission; plant deformation	Ladybug (insect) (larva and adult); hoverfly (larva)	Feeds exclusively on aphids
Mosquito	Bites; spread of viruses, benign diseases in mammals	Gambusia (fish)	Feeds on mosquito larvae
Bombyx caterpillar (moth)	Weakening of the plant making it vulnerable to other diseases or insect pests	Bacillus thuringiensis (bacteria)	Following paralysis, causes septicemia in the caterpillar
European corn borer	Devours corn leaves and causes the cobs to fall off	Beauveria (fungus) Trichogramma (insect)	The spores of the fungus germinate on the corn borers and kill them. Lays its eggs in the pyralid eggs; the larvae devour the contents of the egg
Whitefly	Punctures the leaves and fruits of the tomato	Encarsia (insect) (adult)	Lays its eggs in those of the whitefly
Horse chestnut leaf miner	Brown color and premature leaf loss of chestnut trees	Dacnusa (insect) (adult)	Lays its eggs in the larvae of the leaf miners
Cochenille	Weakening of the plant due to taking of sap; seriously impairs the photosynthetic activity of the plant	Beetle (insect)	The larva of the ladybug feeds on mealybugs

A particular form of biological control **is autocidal control:** sterile males are released in very large numbers to compete with wild males and thus effectively limit the offspring of females. This method is particularly suited to greenhouse crops but requires the presence of an organism producing these sterile males.

A similar method consists **of using pheromones to attract males in the traps and thus limit their number.** A pheromone is a chemical signal emitted by the virgin female to attract the male for reproduction. Research made it possible to decipher this signal and reproduce, allowing the selective capture of males. Pheromones are an ecological control method. Contrary to insecticides, these compounds, diffused locally and in very low concentrations, do not generally present a risk to health and the environment.

This method, similar to mating disruption, is generally very effective and does not have any adverse effect on health or the environment, at least as long as the pheromone dispensers are not opened or left on the ground or in the water. However, it must be implemented on large areas to be genuinely effective, multiple farmers must join together and install the hormone diffusers at the same time and at the right moment while taking into account the life cycle of the pest.

Examples of biological control are described below in the boxes. It was possible to deploy all these methods thanks to the knowledge of insect pests and/or crop auxiliaries. Depending on the method, they target the larvae, adults or the reproduction phase of the insect pests:

1. Use of a small wasp *(trichogramma)* **to destroy the larvae of the corn borer** which cause substantial damage to corn and other crops.
2. Biological control of the millet earworm.
3. Prospects for biological control of fall armyworm.
4. Capture of male banana weevils with pheromone traps.
5. Sexual confusion also using pheromones.
6. Use of Bacillus thuringiensis (Bt) toxins in vegetable and potato production.
7. Use of a fungus, Beauveria bassiana, to control various insects.
8. Stimulation of plant defenses with eliciting substances or biostimulants[27]
9. Presentation of push-pull
10. Integrated approach with a combination of various biological control methods *(example of the control methods used for the vegetable fly in Réunion).*
11. Biological control through habitat conservation and management: the need to work at the landscape level.

Some preliminary remarks concerning these biological control methods

1) One of the current limitations of many biological control methods is their often high cost to farmers. Crop protection companies are aware that the future of many of their registered pesticides is compromised due to their toxicity and have realized that so-called "biocontrol" products represent a very promising market in the future. Initially, however, they take in very attractive margins on these products, as was the case for glyphosate when it was approved.

For example, the cost per hectare in France of a Spinosad application is currently 5 to 10 times more expensive than a chemical insecticide based on pyrethrins or neonicotinoids! It is a fermented product derived from the mixture of two toxins *(Spinosyn A et D)* secreted by a soil-dwelling bacteria, Saccharopolyspora spinosa. Spinosad is controversial but allowed in organic farming in Europe.

Consequently, whenever possible, priority should be given to low-cost biological control methods that are within the reach of farmers. For example, in home gardening, the use of old mosquito nets or preparations based on chili, garlic, hyptis spicigera, caïlcedrat, certain ashes and other NPLCs that can be safely prepared at home *(cf. (see Topic 5 of this module)* **are alternatives that should be prioritized from now on.**

2) Certain public health emergencies should lead to the funding of biological control methods. For example, vegetable garden operators in many parts of Africa (especially in peri-urban areas) use various highly toxic pesticides without being aware of (or observing) the recommended doses and frequencies of treatment, nor observing the duration of the products' persistence and therefore the date of the last application prior to marketing.

According to surveys conducted by ITRA (Togolese Agricultural Research Institute) in the vegetable garden areas around Dapaong, three quarters of the pesticides used to treat vegetable crops are insecticides or acaricides, mainly Lambda-cyhalothrin, which pose significant human health and environmental risks *(cf. Module II, topic 1)*. In Africa, treatments with this active ingredient are sometimes applied in peri-urban vegetable growing areas twice a week on vegetable crops and pure cowpea crops.

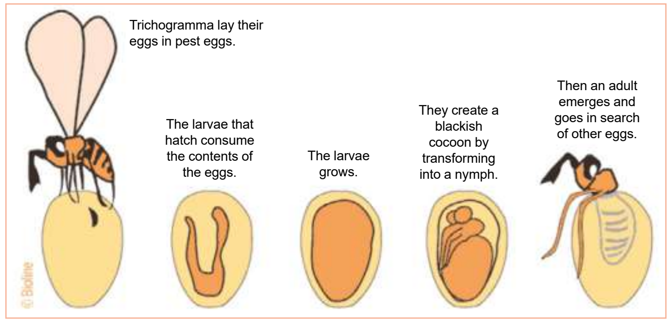
Due to its toxicity to humans and insect pests, it is considered to be of high concern in Europe. On 06/20/2019, the EU moreover reduced the maximum residue limits of this active ingredient (cf. https://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=CELEX:32019R1015).

Consequently, biological control alternatives that make it possible to forego Lamda-cyalothrin *(or dimethoate, chlorpyrifos, Dichlorvos, etc...)* **in vegetable crop plots could be subsidized and widely diffused.**

1 - Use of Trichogramma to destroy the larvae of various predatory insects

Trichogramma are tiny Hymenoptera that destroy predatory insect populations in various crops. Their use has been developed by INRAE in France since the 80s and this method of biological control has been proven on a large scale in corn, vines, etc....
For example, with corn, when flights of pyralid moths have been reported, plates of Trichogramma brassicae specific to the borer are introduced to the plots (time requirement = 15 to 20'/ha). The Trichogramma then lay their eggs in the moth's eggs and their larvae destroy them. These Trichogramma are effective parasites that completely destroy their host and whose effectiveness is not inferior to that of previously used insecticides (Source: ARVALIS - AGRICULTURAL OUTLOOK • N° 341 • JANUARY 2008).
The cost per hectare of Trichogramma is currently limited in Europe (€ 25 to 30/ha) and each plate contains 3 to 4 generations at different stages that provide crop protection for 2 months.
This technology has now spread to several Latin American countries and can be used to control about 20 pests of various crops including cotton, food crops (including beans), sugar cane, etc. (cf. https://www.ideassonline.org/pic/doc/BrochureTrichogramma.pdf). On the other hand, in order for the Trichogramma to remain active before being introduced in the fields, they must be protected against extreme heat and excessively dry periods, which can limit their use in the hot regions of the world which include the Sahel zones.
It should be noted that Trichogramma that act as crop auxiliaries occur naturally and are more frequent **when the biodiversity of plants is high in the plots and when there are ample refuge areas around the plots**(https://lasef.org/wp-content/uploads/BSEF/118-2/1641_Lamy_et_al.pdf).

Pyralid moth larvae on corn
Source: http://www.fiches.arvalisinfos. fr/fiche_accident/



Cycle of Trichogramma
Source for this Trichogramma cycle and the photos above: https://www.insectosphere.fr/traitement-bio-contre-pyrale-buis/47-trichogrammes-anti-pyrale-buis-3760221163935.html

Actual size of Trichogramma

Enlarged Trichogramma

Plate containing multiple generations of Trichogramma[29]

Manual installation of the plates every 20m x 20m on a leaf of corn (time required = around 15' per ha)[30]

[29] Photo source: https://www.lesterrenales.com/wp-content/uploads/IMG_4528-683x1024.jpg.
[30] Photo source: https://wikiagri.fr/uploads/article/cover/3546/home_big_Trichogramme__De_Sangosse_.jpg

2 – Biological control of the millet leaf miner

Source: articles of Boukary Baoua Ibrahim and M. Laouali Amadou (Niger researchers) https://www.researchgate.net/publication/281816567_La_lutte_biologique_contre_la_Mineuse_de_l'epi_Heliocheilus_albipunctella_De_Joannis_Organisation_et_evaluation_des_lachers_du_parasitoide_Habrobracon_hebetor_Say)

Summary of the articles by these two authors: The millet ear miner, Heliocheilus albipunctella De Joannis *(Lepidoptera, Noctuidae)* is one of the most harmful millet pests in Niger (and in other Sudano-Sahelian countries). Ear infestation levels can reach 95% with grain yield losses ranging from 8 to 95% depending on the area and the year. Pest damage is often recognized at the end of the season after farmers have invested all their efforts.

The National Institute for Agricultural Research of Niger (INRAN) in collaboration with the Université Dandicko Dankoulodo de Maradi (University of Maradi/UDDM) have developed a technology based on **the release of Habrobracon hebetor Say, an ectoparasitic hymenoptera of lepidopteran larvae.**

Leaf miner damage to millet ears [31]

Habrobracon hebetor and the millet leaf miner larva - Source: CSAN Niger Csancfsn

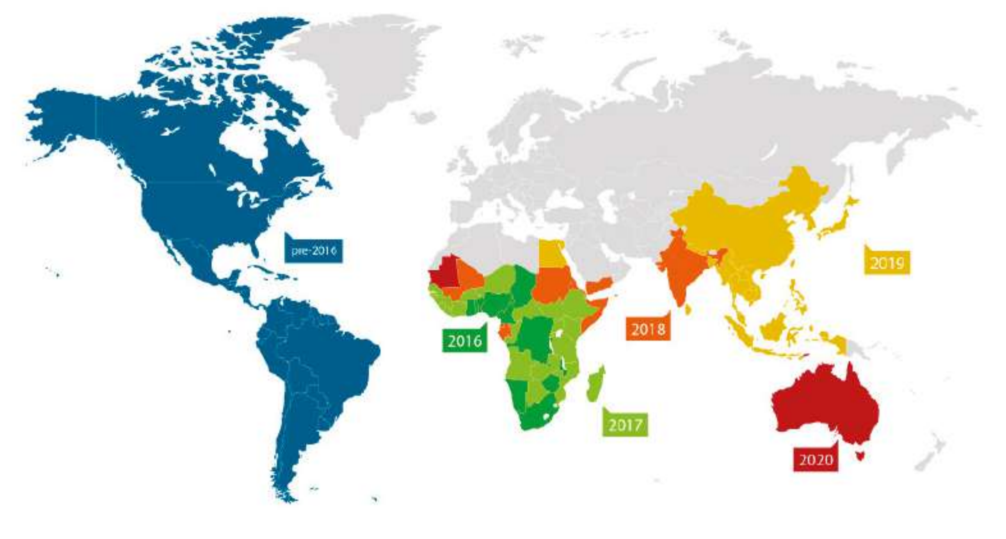
3. Prospects for biological control of fall armyworm

Fall armyworm damage on a male corn cob
Kaédi Mauritanie – January 2020
Photo V. Beauval

Fall armyworm
Kaédi Mauritanie – January 2020
Photo V. Beauval

[31] Photo source: https://www.cirad.fr/nos-recherches/resultats-de-recherche/2014/combattre-l-erosion-et-reguler-les-bioagresseurs-du-mil-conflit-ou-synergie.

As the map below shows (Source FAO: http://www.fao.org/fall-armyworm/faw-monitoring/faw-map/fr/), the armyworm spread across the various continents from 2016 to 2020 (that is, in a mere 5 years!) and **causes extensive damage to various crops including corn.** Its rapid spread can be attributed to globalization, but also by the fact that the moth *(Spodoptera frugiperda, a member of Noctuidae)* is able to travel up to 100 km in a single night!



This moth has **several natural enemies** in its native environment, the Americas. They help to limit its proliferation. These include ants, earwigs, bugs, **parasitoids** *(see micro-hymenoptera)* and other beneficial organisms. These crop auxiliaries are beginning to be studied in Africa.

One hope would be to identify Hymenoptera parasitizing eggs or caterpillars such as **Trichogramma** used for corn *(first example above)* or **Habrobracon hebetor** parasitizing eggs and caterpillars of the millet leaf miner (second example) or **Telenomus remus** or **Cotesia icipe, parasitoids** already present in some West and Central *African countries (cf. work of various research teams including IRD, Centre for Agriculture and Biosciences International = CABI, etc...).*

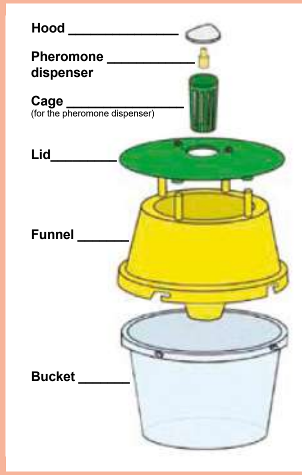
Other possible control methods include: (1) conventional chemical methods; (2) GMO Bt corn, however, the *Spodoptera frugiperda* caterpillar has reportedly started to show resistance to "Bt corn" (http://www.fao.org/3/a-i7471f.pdf) or again (3) pheromone traps (cf. box below).

Trap model for use in destroying the fall armyworm (= funnel trap or universal trap)
Source: http://www.fao.org/3/i9124fr/I9124FR.pdf

Male moths are attracted by a **pheromone** similar to that of the females and stuck in a round bucket **with an insecticide pellet** that kills the captured moths. This type of trap captures a large number of moths. It can be used for prolonged periods.

The traps must be placed in the field one month before planting. Counting **should begin as soon as the crop** emerges in order to better detect the first arrivals of noctuid moths.

The trap is hung from a pole or branch about 1.25 m above the ground and set up on the edge of the field so that it is always 30 cm above the crop height. The trap must be set up regularly taking into account the plant growth. One trap **must be set up for 1 to 2 ha.**



4 – Use of pheromones to control the banana weevil

Source: http://transfaire.antilles.inra.fr/spip.php?article8

The black weevil Cosmopolites sordidus *(Coléoptères, Curculionidae)* is the main pest of banana and plantain. The female lays her eggs in the bulb of the banana tree. After the eggs hatch, the larvae dig channels in this bulb, damaging the insertion points of the primary roots. The banana is weakened and could break or fall.
Traps that use sordidin *(a specific pheromone)* capture **male weevils** and are effective in controlling banana weevils. The population can be monitored with traps on the plots (4 traps per hectare) or the traps can be used for mass trapping in the most severely infested fields (16 traps per hectare) or along the periphery of the fields by creating a "barrier" to limit colonization.

For this method to remain effective over time, it must be supplemented with other control techniques such as rotations, fallowing and other biological control agents such as entomopathogenic fungi like Beauveria bassiana and Metarhizium anisopliae. This is referred to as "integrated pest management" *(see Philippe Tixier, CIRAD "Lutte intégrée contre le charançon noir dans les systèmes de culture bananière" (Integrated control of the black weevil in banana cropping systems).*

Black banana weevil

Pheromone trap
https://bsvguyane.wordpress.com/le-charancon-du-bananier-cosmopolites-sordidus/

5 – Sexual confusion also using pheromones.

Source: https://fr.wikipedia.org/wiki/Confusion_sexuelle and the Bioprox site
It is a method widely used in Europe, for example, for the codling moth, grapevine worm or box elder moth,... This sexual confusion is achieved by using synthetic pheromones reproducing the hormonal scent of females and specific to each species. **An area is saturated with female pheromones, making it more difficult for males to find females for mating.** *NB: In France, the company Bioprox produces, with the support of INRA, 72 different synthetic pheromones.* This method limits the production of eggs and therefore of larvae which cause direct damage *(destruction of flower buds, consumption of fruit)* or indirect damage *(wounds which are entry points for secondary parasites).*

Diffusers containing pheromones **are installed in the plot.** They come in the form of links, sprays or capsules. The capsules protect about 20 m², so you need about 500 per ha. The sprays cover a larger area = 5 000 m² (0.5 ha).
To be effective, sexual confusion must be used homogenously and on a sufficiently large area, estimated at a minimum of 5 ha. **It requires farmers to work together to ensure effective protection of their plots.** The periphery of the protected area is not immune to the penetration of female moths fertilized outside this area and the use of insecticides is sometimes necessary along the edge of the plots.

6 – Use of a fungus, Beauveria bassiana, to control various insects.

Source: https://fr.wikipedia.org/wiki/Beauveria_bassiana

Beauveria bassiana, formerly known as Tritirachium shiotae, is a fungus that grows in soils and causes diseases in various insects by acting like a parasite. The fungus causes "white muscardine" disease. When the spores come in contact with the host insect, they germinate and penetrate the interior of the body, eventually killing it by using it as a food source. A white mold develops on the corpse, producing new spores. The contaminated insect acts as a vehicle for the fungus until its death.

This fungus does not appear to infect humans or other warm-blooded animals. Most insects living in, on, or near the soil have developed natural defenses for this fungus. On the other hand, **many aerial insects are sensitive to it.** However, other insects could develop, through natural selection, resistance wherever it is used intensively.

It is used to control termites, banana weevil, Paysandisia archon, red palm weevil, etc.. Its use for the control of **mosquito vectors of malaria** is being evaluated: the microscopic spores are sprayed on nets. Its use is also being studied on soil pests, such as the wireworm (Agriotes obscurus L). **Also note that Beauveria hoplochelii controls sugarcane grubs very well.**

Cultivation of Beauveria bassiana

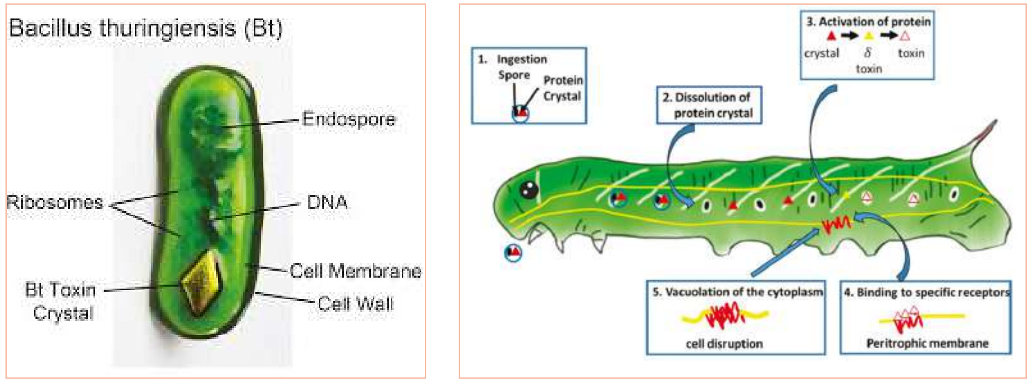
Attacked insect

Attacked bug

7 - Use of Bacillus thuringiensis (Bt) toxins in vegetable and potato production.

Source: https://tel.archives-ouvertes.fr/tel-01674214/document

Better known as Bt, this bacterium is naturally present in the soil, air and water. Some of the 80 species listed are insecticides because they produce toxin crystals (more than 150 Cry proteins have been identified). Once ingested, these toxins are released into the insect's digestive tract and cause septicemia by destroying its intestinal walls, resulting in the insect's death. Bt-based products are biocontrol products.



Cross-section of Bacillus thuringiensis and mode of action:
Source: https://www.researchgate.net/figure/Mode-of-action-of-Bacillus-thuringiensis-in-Lepidopteran-caterpillar-1-ingestion_fig1_318039006

Today, such Bt-based products are estimated to account for 50% of the world market of bio-insecticides, representing **3 to 4% of the total insecticide market.** Commercial Bt formulations consist of spore and crystal preparations obtained from cultures grown in fermenters. These products have no pre-harvest interval (PHI) constraints and are generally available as wettable powders or liquid concentrates for spraying. Following dilution in water, the solution should be sprayed on the entire foliage of the plant to be treated, making sure to cover all suspended parts *(leaves and stems).*

When exposed to sunlight and environmental microorganisms, Cry toxins degrade rapidly and their duration of action is limited to a few hours. Bt-based products cannot be used as a preventive treatment and, in case of heavy infestation, the curative treatment should be repeated every 7 to 10 days to eliminate newly hatched larvae. (source: https://www.jardinsdefrance.org/la-lutte-biologique-avec-bacillus-thuringiensis/).
There are several strains *(or serotypes)*of Bt that, depending on the nature of the toxin synthesized, enable specific control of a particular insect group. *Bacillus thuringiensis* based treatments are effective against attacks by:

- **Lepidopteran larvae:** budworms, noctuid moths, cabbage white (upon hatching), codling moth, leek and olive moths, etc. As soon as a large number of young caterpillars appear, it is recommended that the treatment be applied quickly given that Bt products are less effective on older caterpillars. It should be noted that, generally, leaf miners cannot be controlled with Bt because they feed on the inner leaf tissue and not on leaf surface so the product cannot reach them.
- **Beetles and their larvae:** Colorado potato beetle, lily beetle,...
- **Diptera:** flies mosquitoes.

In Europe, each Bt treatment costs between 20 and 30 euros per hectare and, if the infestation is severe and requires repeated treatments, this can lead to dismissive costs, at least for crops that do not generate enough added value per unit area.

8 - Use of "eliciting" substances

Source: http://ressources.semencespaysannes.org/document/fiche-document-43.html

Plants are fixed organisms that cannot flee from attacks. As a result, over time, they have learned to develop internal defense mechanisms. When an insect or a fungus attacks, for example, the plant can reinforce its walls to defend itself or produce chemical compounds to attack the pest.

During an attack, a specific compound circulating in the plant will inform it of the attack. This substance is called an elicitor *(or Natural Defense Stimulators = NDS)*. Scientists are working on a solution that harnesses this natural reaction of the plant and hope to identify products that will mimic the attack, "tricking" the plant into believing that it is under attack and that it must therefore bolster its natural defenses.

The use of micro-organisms or elicitor compounds capable of activating at least one of the typical defense responses of plants without infection can therefore be an effective solution for protecting plants efficiently and long-term against the stresses they are exposed to.

Products that stimulate plant defenses can be made from certain marine algae, plant extracts or micro-organisms...

More and more companies are developing such products which are much safer than pesticides. For example, Elephant Vert S.A. markets a product in Morocco that strengthens the cell wall of certain plants thus making them more resilient in the event of attack: http://wordpress.elephantvert.ch/content/uploads/2017/10/Fiche-Reysana.pdf

For more information on this subject, cf. https://fr.wikipedia.org/wiki/%C3%89liciteur

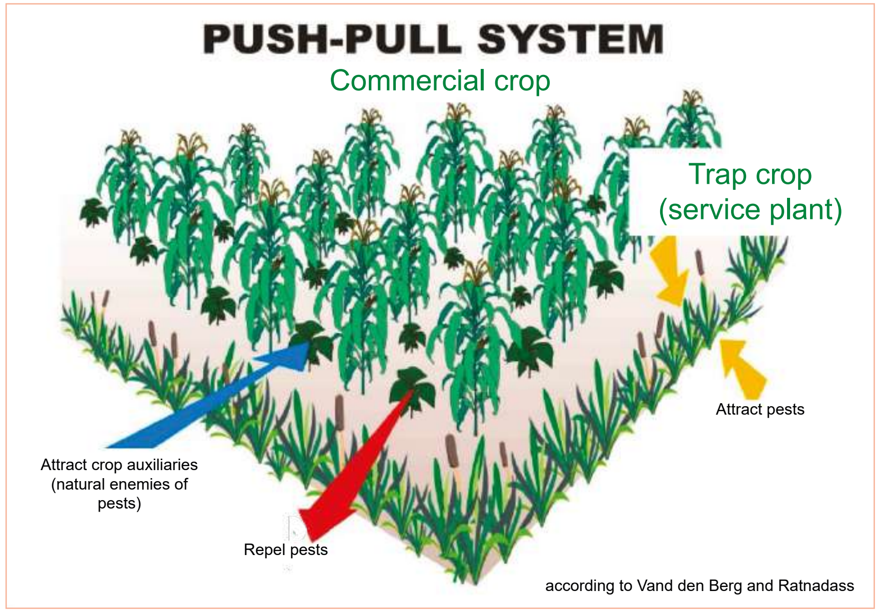
Practical application on cotton in Mali without the use of purchased products!
Source: https://coton-innovation.cirad.fr/content/download/4856/35361/file/ITKInnovation-14-Mali%20Ecimage.pdf

According to recent research by researchers at the Malian IER and CIRAD, **complete topping of the cotton plant reduces insect pest populations by an average of more than 65% from the topping period to the end of the cotton cycle.** 20% topping of cotton plants would also have an insect-repelling effect and reduce subsequent use of insecticides.**This effect is due to the production of eliciting substances by the topped cotton plants** which strengthen their walls making them less susceptible to larvae and piercing-sucking insects.

Extracts from this CIRAD-IER file: "The topping of the cotton plant is performed 10 days after the first flower blossoms, that is, approximately 65 days after its emergence, which corresponds to the emergence of the 15th fruiting branch. On this date, the first two insecticide treatments have already been applied as well as the application of urea and use of the weeding-hilling technique. On average, three men/day are needed to top 20% of the cotton plant and 6 - 7 men/day are needed for complete topping of cotton plants".
"Topping is not difficult, but is time-consuming, especially because of the movement required within a plot. When carried out in accordance with the recommendations of this technical data sheet, topping does not lead to a loss of production. According to 2015 data, its economic benefit to farmers lies in a reduction of over 40% in insecticide applications".

9 – Push-pull - Sources Wikipedia and Cirad

Also known as repellent-attractant or push-pull, this is a biological control approach that involves "chasing" insect pests away from a main crop and "luring" them to the edge of the field. This method is relatively complex in terms of its implementation and depends on the arrangement of plants with the biological or chemical ability to repel, attract or trap insects. For example, it must be ensured that plants, which attract insect pests and are situated outside the plot, remain attractive throughout the crop cycle *(at least as long as it is susceptible to this pest)*. The best arrangements avoid the use of synthetic insecticides or GMOs.



The technique was developed in Kenya by the Indian entomologist, **Zeyaur R. Khan** of ICIPE *(International Center of Insect Physiology and Ecology)* and is used in East Africa, especially in Kenya, to control insect pests of corn (cf. https://fr.wikipedia.org/wiki/Push-pull_(agriculture). CIRAD has also worked on this topic in Africa. Some of this work is summarized in the paper by Alain Ratnadass et al entitled: "Stratégies Push-Pull au Cirad" (Push-pull strategies at Cirad) (cf. https://agritrop.cirad.fr/572796/). The conclusions and perspectives described in this document are as follows:

• Evidence of synergistic push and pull effects of the product GF-120 *(mixture of spinosad in an amount of 0.02% and food attractants based on sugars, plant proteins)* on 2 different groups of fruit flies and via 2 opposite processes.

• Reduction of Helicoverpa armigera infestation and damage to okra thanks to planting of a pigeon pea belt around the plot via bottom-up (trap plant) and top-down effects *(better vegetative development of okra, attraction of less harmful piercing-suckers attracting spiders that regulate the larvae of the moth).*

• Evidence of reduced infestation of tomatoes by *Helicoverpa zea* with a corn belt.

• Significance of the Java sweet corn variety on which larvae do not develop as well and remain longer on the silk where they are more susceptible to predation.

The **"push-pull"** technique has also been tested empirically by the AVSF Kita team who combined organic cotton, okra and Guinea sorrel in well-defined arrangements. The results were satisfactory but these tests should be repeated to ensure their effectiveness, or even tested on other plants.

10 - Integrated pest control using a combination of several biological control methods

The control of vegetable flies on Réunion Island has been developed and disseminated by Cirad, the Chamber of Agriculture, the Fdgdon, farmers' groups, etc.... It uses various non-chemical methods summarized in the attached diagram:

The technical booklet of the Gamour program presents this combination of biological control methods in a simple and educational way (cf. http://www.ecophytopic.fr/concevoir-son-systeme/livret-technique-gamour-gestion-agroecologique-des-mouches-des-legumes).

The augmentorium technique:
First developed in Hawaii, it was developed on Réunion Island to control vegetable flies. It is a tent-like structure in which infested, pierced fruit collected in the field is regularly deposited. The key to the structure is the mesh size of the nets placed on the top. Indeed, the structure must make it possible to **keep the pests inside while allowing crop auxiliaries, which parasitize these pests, to enter and leave.**

The resulting effect is twofold:
• the biological cycle of the insect is broken by destroying the multiplication sites;
• the insect's natural enemies multiply.
This tool is therefore both a prophylactic method and a biological control method.

Sexual trapping attracts male flies with pheromones and therefore reduces female fertilization.

Trap **plants** such as corn or forage cane are also used to trap flies.

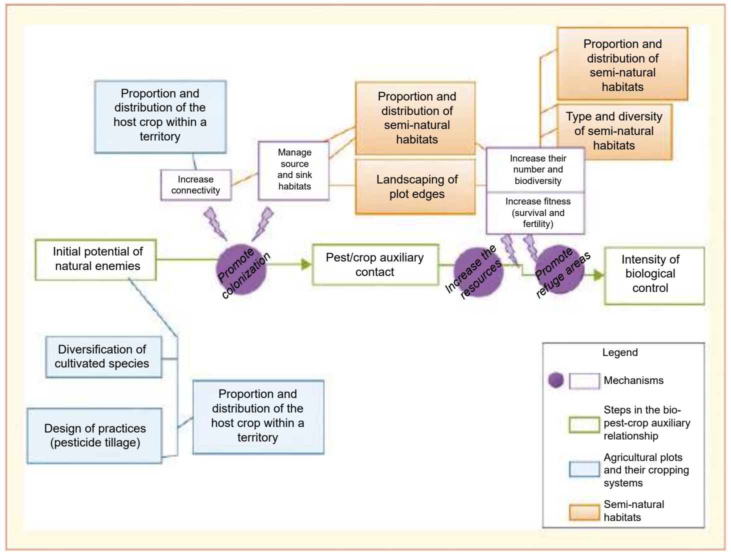
11 - Biological control through habitat conservation: the need to reason at the landscape level) – Sources Cirad et Inrae

In 2013, François-Régis Goebel *(Cirad entomologist)* published an article entitled “Changer d’échelle: De la parcelle au paysage” (Changing the scale: from the plot to the landscape”). Here are some extracts from the introduction to this article: “For the last twenty years, pressure from insect pests on agriculture has grown. **This growing pressure is due to the expansion of monoculture farming and the intensification of cultivation practices that modify landscapes and reduce biodiversity.** It is amplified by climate change, which encourages insect migration and modifies their biology.

Fighting against this growing pressure while reducing or stopping the use of pesticides, means one must act not only at the plot level but also at the landscape level. This change of level allows the harnessing of biodiversity to regulate pests and also to coordinate the practices of stakeholders, as shown by the fight against pests of sugarcane and cotton.

However, this requires detailed knowledge of the interactions between populations of pests and their auxiliaries on the one hand, and landscape components, biodiversity and human activities on the other, which gives rise to new fields of transdisciplinary research”.

In an article entitled "Comment favoriser la régulation biologique des insectes de l’échelle de la parcelle à celle du paysage agricole pour aboutir à des stratégies de protection intégrée sur le colza d’hiver?” (How to promote insect biological regulation from the plot level to the agricultural landscape level to achieve integrated protection strategies on winter rape), published in 2012 in the OCL review N°83, Muriel Valantin-Morison (Inrae) presents the following diagram of insect-natural enemy-crop plot **interactions and the expected effects of semi-natural habitats and agricultural practices at the landscape level.**



This approach is conceptualized by stakeholders advocating **biological control through habitat conservation and management.** As indicated by the exchange platform for the implementation of agroecology[32], **the unique aspect of this approach involves modifying the environment to favor auxiliaries and disadvantage pests of one or more crops.** The goal is to redesign crop systems and landscapes **in order to harness as much as possible natural regulation processes.**

The sustainability of this approach differs from biological control “through augmentation or flooding”, which consists, for example, of releasing parasitoids that the farmer must purchase each year. Indeed, the goal is to maintain naturally occurring auxiliary populations and not have to introduce them every year.

This complex yet exciting process combines two approaches: “top-down” regulation and “bottom-up” regulation”.

As stated below in the abstract of Noelline Tsafack Menessong's dissertation defended on July 10, 2014, these landscape approaches are crucial when it comes to better understanding what is happening in the cotton fields (cf. https://www.cirad.fr/actualites/toutes-les-actualites/articles/2014/science/ecologie-du-paysage-et-lutte-integree-en-afrique).

Which landscapes reduce the presence of moth pests in cotton fields in Benin? Answer: those that include corn crops.

To obtain this result, Noelline Tsafack analyzed landscapes within a 500 m radius around 20 cotton plots in northern Benin over two agricultural seasons. **This kind of research on a pest, which takes into account the ecology of the landscape, makes it possible to improve the effectiveness of integrated pest management.**

The pest monitored is the noctuid moth *“Helicoverpa armigera”*. This moth lays its eggs on several cultivated plants (mainly cotton, tomato and corn). The flowers and part of the plants are then eaten by the larvae. And in northern Benin, Helicoverpa armigera can reduce cotton yields by up to 62%!

According to the findings obtained by Noelline Tsafack, Helicoverpa armigera larvae are less prevalent in cotton plots surrounded by corn fields because the moth is attracted by the flowering corn. Thus, corn fields located near cotton crops can limit the damage this moth causes to cotton fields.

Remarks:
- This once again demonstrates the limits of monocultures and the importance of diversified landscapes. However, in northern Benin from the 1960s to 1980s, the extension services of cotton companies promoted blocks of about 20 ha cultivated with the same cotton variety…
- Moreover, better protection of cotton is good, but not proposing an integrated pest management method to protect corn would be dangerous for the food security of farming families!

[32] https://osez-agroecologie.org/images/imagesCK/files/syntheses/f454_synthese-technique-lutte-biologique-par-conservation-et-gestion-des-habitats.pdf

TOPIC 5:
Improve and expand local production of biopesticides and natural preparations of low concern (NPLCs).

Appendix 4 of this guide includes a survey guide for collecting information on the preparation and use of biopesticides and NPLCs produced in the villages of training participants. This survey needs to be completed before covering this topic.

Reminders about NPLCs and biopesticides

These two types of products are rarely differentiated in Africa and in other countries of the Southern Hemisphere although farmers tend to have extensive knowledge in this area. It is therefore important to clarify **the differences between these two categories.** Although both are natural preparations, they differ in terms of their toxicity to humans and the environment.

1. Natural preparations of low concern (NPLC) are not plant protection products and do not require marketing authorization (= MA). This point is important because it facilitates independent production of preparations on the farm and consequently the autonomy of the farmers. With respect to NPLCs, French legislation distinguishes between basic substances and natural substances for biostimulant use.

- **Basic substances with phytosanitary value** but which are mainly used for purposes other than plant protection (some are foodstuffs*)*. They are subject to a simplified approval procedure in France, but **must be approved at the European level for one or more specific uses.** 19 basic substances listed in the official table below are currently authorized, 10 of which can be used in organic farming.

  Note: In France, among these basic substances, the Technical Institute of Organic Agriculture (ITAB) prohibits the use of sea salt and clay coal.

List of approved basic substances (updated 28 May 2018)		
active substances	**usage**	**UAB**
Sodium bicarbonate	fungicide for fruit trees, vines, vegetable crops, ornamental crops	ongoing evaluation
Beer	covered slug trap, all crops	authorized
Clay carbon	vine fungicide (esca)	ongoing evaluation
Chitosan	fungicide and bactericide for small fruits, vegetables, crops for animal feed; cereals, potatoes, beets (seeding and growing)	authorized
Diammonium phosphate	attractive (mass trap) for fruit flies, Mediterranean fly	ongoing evaluation
Willow bark	fruit (apple, peach) and vine fungicide	ongoing evaluation
Mustard seed flour	fungicide (treatment of wheat and spelt seeds: decay)	authorized
Fructose	stimulator of apple tree natural defense mechanisms (codling moth)	authorized
Sunflower oil	tomato fungicide	authorized
Calcium hydroxide/ slaked lime	fruit fungicides (Neonectria galligena canker)	authorized
Lactoserumlwhey	curcubitaceae fungicide	authorized
Lecithins	fungicide for fruit, vegetables, vines, ornamental crops	authorized
Nettle	insecticide, fungicide, acaricide for fruit, vegetables, vines, ornamental crops	authorized
Hydrogen peroxide	fungicide and bactericide (soil) solanaceae, lettuce, flowers	No
Horsetail	fungicide for apple, peach, vine, cucumber, tomato, ornamental crops	authorized
Saccharose/sucrose	natural defense stimulator for sweet corn (borer) and apple (codling moth)	authorized
Sea salt	vine fungicide and insecticide, mushroom fungicide	ongoing
Talc	insecticide and fungicide in arboriculture and fungicide in viticulture	No
Vinegar	fungicide and bactericide (seed or plant treatment) cereals, tomato, carrot, ornamental crops	authorized

- Natural substances with biostimulant effects, most of which were identified by the elders and constitute "farmer knowledge", some of which have been scientifically validated. More than 200 plants are currently authorized in France (see site https://www.legifrance.gouv.fr/affichCodeArticle.do?cidTexte=LEGITEXT000006072665&idArticle=LEGIARTI000006913464&dateTexte=&categorieLien=cid). This list includes many tropical plants such as acacia senegalensis (gum tree), *(gum tree)*, garlic, tropical almond, basil, carob tree, lemon grass, clove, Cola acuminata, cilantro, turmeric, eucalyptus, fennel, fenugreek, ginger, ginseng, clove, carob, guinea sorrel, lemongrass, various mints, nutmeg, orange trees, nettles, pawpaw, chili, sage, tamarind, etc...

Animal products such as cow urine and dung are also frequently mentioned by farmers in the Southern Hemisphere and can be included among the NPLCs. If their effectiveness as fertilizers no longer needs to be demonstrated, the scientific references in terms of plant protection remain to be established[33].

All NPLCs classified as natural substances for biostimulant use and **obtained through a process accessible to any end user,** i.e. untreated or treated only by manual, mechanical or gravitational means, by dissolution in water, by flotation, by extraction with water, by steam distillation or by heating only to eliminate water, can be used in organic agriculture.

Additional remark concerning the NPLCs: A French association, ASPRO-PNPP *(association for the promotion of NPLCs)*, submitted, to the Ministry of Agriculture and ANSES in 2017, a request for evaluation of nearly 800 plants and natural elements. It should be noted that in Germany, the United Kingdom, the Netherlands, Austria and Spain, natural preparations are included in specific lists that do not require the inclusion of basic substances in the European list. As a result, many NPLCs are not approved in France are now marketed in these countries.

2. Unlike NPLCs, biopesticides require MAs because they are able to kill *(cf. suffix cide)* insects, fungi, etc... and they are likely to have, beyond a certain dose, **negative effects on human health and also on pollinators and other beneficial insects.** Among these biopesticides, the case of tobacco and neem *are briefly mentioned below (we could also mention natural pyrethrum or Dalmatian pyrethrum = Tanacetum cinerariifolium).*

Tobacco or neem-based preparations are often used in Africa and their toxicity is rarely mentioned. However, these plants contain compounds that are highly toxic to humans if their concentrations in the preparations are high and the dose absorbed during the preparation of the pellets and during spraying exceeds certain thresholds (which cannot, however, be easily measured).

- For the nicotine contained in tobacco, the toxicological sheet of the INRS *(French Institute for Health and Safety at Work)* notes that, for humans, "acute nicotine intoxication can lead to death". Tobacco leaf preparations were used in numerous Northern countries in the 1960s. Given their toxicity to humans (*cf. health incidents involving farmers who used them to treat their crops)*, nicotine-based insecticides have been withdrawn from the market in most countries and are now banned (but they are still sold over the counter in some countries, including India ...).

- The azadirachtin contained in the leaves and above all the seeds of neem has multiple, impressive properties *(insecticide, fungicide, nematicide, consumption inhibitor and growth inhibitor...)*. This compound is effective against more than 200 insects including field pests such as aphids, white flies, Scarabaeidae, white worms and cutworms, borers, diamondback moths, noctuid moths, locusts, mites and pests of stored products (cowpea bruchids, weevils). Its odor and bitter taste also have a repellent effect on adult beetles and whiteflies. However, azadirachtin has no effect onmealybugs,lice, bugs, fruit flies and mites.

[33] In order to discern what is true and what is false when it comes to "cowpathy", the current Indian government has set up a scientific committee whose mission is to study the curative properties of cattle dung and urine (cf. https://www.willagri.com/2018/03/12/la-filiere-de-lurine-de-vache-en-inde/).

As a consequence of the above, and in particular of its broad spectrum of action, the registration of azadirachtin-based products is the subject of debate in several European countries (cf. https://fr.wikipedia.org/wiki/Azadirachtine). Recent studies show that this compound has negative impacts on aquatic environments, that it causes atrophy in young bees and some studies suggest that it is an endocrine disruptor (cf. https://www.sagepesticides.qc.ca/Recherche/RechercheMatiere/LoadPrintModal?MatiereActiveID=220).

It is therefore important to remember that if a natural product is toxic to numerous insects or fungi, it can also be toxic to humans. If it must be used due to necessity, it is absolutely imperative that one is properly protected. It is not a matter of advocating the cessation of the use of neem leaves and seeds, which abound in many African villages, but of being cautious and taking, when using them, precautions equivalent to those concerning synthetic pesticides.

Examples of the promotion of these biopesticides and NPLCs in Africa

Chili, garlic, onions and neem, ingredients often used in West Africa
(Photo IRD)

Treatment with a biopesticide based on chili, garlic and neem leaves
(Photo IRD)

Numerous NGOs and farmers' organizations promote biopesticides and natural preparations of low concern, but generally fail to distinguish between these two types of products in terms of toxicity to humans and/or the environment.

Three examples of the use of biopesticides and/or NPLCs are presented below: (1) The activities of a project funded by the FFGM from 2014 to 2018 in northern Togo and implemented by AVSF and RAFIA, a local NGO and an OPA, UROPC-S; (2) training activities on these topics by the Malian CNOP; (3) tests carried out by an AVSF team and the Union of CUMAs of Kita Cercle in Mali.

Example 1: "Sustainability and resilience of family farming in the Savannah" project - Togo

27 types of natural preparations were identified by the project team *(see list with composition and use in Appendix 10)* and 5 preparations were tested and disseminated over 3 seasons in rainfed crops and vegetable crops in the 6 cantons where the project intervened in partnership with UR-POC-S groups. These 5 preparations are the following:

N°	Composition	Crops treated	Area to be treated
1	500 g of neem seeds + 500 g onion + 100 g onion + 50 g chili + a pinch of soap	Tomato, cotton, chili, cowpea during the whole cycle, apple cabbage	$400m^2$
2	1 kg of neem leaves + a pinch of soap	Young cabbage or tomato	$400m^2$
3	150 ml of neem oil + a pinch of soap	3-leaf tomato (low dose), apple cab-bage, flowering pepper, flowering cotton, guinea sorrel, okra	$400m^2$
4	50 g chili + a pinch of soap	Young cabbage Trichogramma (insect)	$400m^2$
5	1 kg of neem leaves + 50 g chili + a pinch of soap	Tomato in bloom	$400m^2$

It is noted that 4 of these preparations contain azarachitine (*(and other active ingredients from neem)* and only one preparation can be qualified as a NPLCs *(the preparation based on chili and soap)*. The soap *(or "omo" in other African countries)* ensures that the slurry better adheres to leaves *(NB: Caustic soaps should not be used as they can burn the leaves)*.

The UROPC-S farmer groups tested 6 different treatment schedules alternating these 5 prepara-tions and found them all to be effective. The costs of production and use of these 5 preparations were established and compared with the costs of synthetic pyrethrin (Decis). However, perfor-mance comparisons were not made. They would be difficult because the majority of the plots have been harvested in stages. **In order to go further, scientific support for the AVSF project team from the Togolese research institute (ITRA) would have been desirable.**

Comparison of the costs of production and use of the 5 preparations with Decis for an area of $400m^2$.

Preparation ingredients	Preparation 1		Preparation 2		Preparation 3		Preparation 4		Preparation 5		Deltamethrin (Decis)	
	Qty (g)	Price (fcfa)	Qty (g)	Price (fcfa)	Qty (g)	Price (fcfa)	Qty (g)	Price (fcfa)	Qty (g)	Price (fcfa)	Qty (l)	Price (fcfa)
Onion	500	150	-	-	-	-	-	-	-	-	-	-
Garlic	100	250	-	-	-	-	-	-	-	-	-	-
Chili	50	75	-	-	-	-	50	75	50	75	-	-
Soap	1	25	1	25	1	25	1	25	1	25	-	-
Neem seeds	500	0	-		150	0	-	-	-	-	-	-
Neem leaves	-	-	1000	0	-	-	-	-	1000	0	-	-
Chemical pesticides	-	-	-	-	-	-	-	-	-	-	0.04	200
Family workforce (base 1000fcfa/ HJ)	1/8 HJ	125	1/8 HJ	125	1/4	250	1/8 HJ	125	1/8 HJ	125	1/8 HJ	125
TOTAL COSTS	**-**	**625F**	**-**	**150F**	**-**	**275F**	**-**	**225F**	**-**	**225F**	**-**	**325F**

Following the presentation of the above table by the AVSF Northern Togo team in charge of monitoring these tests, observations by members of the farmers' organization (UROPC-S):

- As neem is present everywhere in the villages, natural treatments based on this plant are less expensive than chemical treatments. On the other hand, the first preparation based mainly on garlic and onion exceeds the cost of a treatment with Decis*(this cost would however be lower when these alliums are self-produced by the family)*.

- The chemical treatment with Deltamethrin *(or Lamda-cyhalothrin)* is, however, ultimately the most expensive given that numerous farmers apply it every week and even twice a week, whereas the long-lasting effect of neem-based preparations does not require such a high fre-quency of treatments.

- One difficulty reported by farmers who use NPLCs **is their conservation.**

- Furthermore, they wish to improve their equipment for larger-scale **production of the prepa-rations** *(for example, to use these preparations on cowpea or cotton plots)*.

Example 2: Training module for farmers of the Malian CNOP on natural treatments and examples of distributed preparations

This straightforward, educational document was prepared by the National Coordination of Malian Farmers' Organizations (CNOP), a union promoting farmer agroecology.
It revisits the principles that must be respected when preparing natural products, the necessary equipment, the need to use them exclusively for this purpose *(and not to also use them for food-related applications)*. The target group is also reminded of the need to protect nature when collecting plants and to protect oneself ("put on gloves") when preparing them.

It then presents the importance of two preparations based on neem leaves and seeds. It also includes multiple preparations *(mostly NPLCs)* to be used based on a diagnosis of leaf damage. For vegetable crops, it recommends multiple treatments *(NPLCs and neem-based biopesticides)*. Finally, this guide presents, on the basis of examples, the importance of collective organization at the local or community level to solve relevant phytosanitary problems.
This CNOP training module is included in Appendix 11.

Example 3: Tests carried out by an AVSF team and CUMA regional union of Kita in Mali (CUMA RU)

The composition and method of preparation of the biopesticide tested and distributed by the AVSF team in Kita are as follows: **2.5 kg neem seeds + 120 ml of crabwood oil** (Carapa procera) + **2.5 kg of diola** *(Chamaecrista nigricans)* **+ 100g of chili** all in a container containing **20L of water** let ferment for 3 days and spray.
This biopesticide is used on all crops in a dose of **20L/ha** and would be very effective when applied properly. According to the farmers who use it, the cost of producing it is about **1000 Fcfa per ha.**

Some UR-CUMA farmers compared this preparation proposed by the AVSF team with an endogenous preparation consisting of **kitchen ash filtrate, chili pepper and Hyptis spicigera leaves**, a plant traditionally used to preserve seeds in the granaries of most of the Sudanian zones of West Africa and not identified by research as a plant with active ingredients as toxic as the azadirachtin in neem. Refer to the site of the French Society of Ethnopharmacology and the numerous references in human and animal pharmacopoeia concerning Hyptis spicigera regarding this subject: http://www.ethnopharmacologia.org/recherche-dans-prelude/?plant_id=3271.

Visually, both preparations appear to be effective on cotton. However, a thorough follow-up of their impacts on cotton and cowpea insects should be carried out as well as a measurement of the yields obtained.
Having different preparations available offers two advantages:
1) using only one preparation risks encouraging the multiplication of resistant insects;
2) the reduction of the use of neem is desirable in terms of human health, preservation of bees, etc...

NOTES