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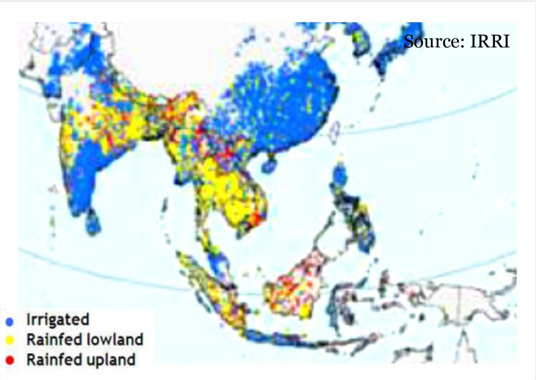
Biocontrol

Management of Brown Planthopper and Other Insect Pests of Rice

Rice most important staple food in Asia



Rice is the primary staple food for more than two billion people in Asia**.** Of the world total of **482 Mio tons** of rice (FAO, 2016-17) **about 89%** is **produced in Asia**.

Insect pests, rodents, and weeds have been sources of high chronic or epidemic losses in production in combination with other stresses. Due to the large area cultivated, rice is beset by a wide array of pests and diseases, affecting all stages of the crop.

Under the pre-scribed goal to formulate comprehensive and hands-on guidance for biological control applications in the framework of IPM, the present leaflet focuses on the use of **insect-pathogenic fungi** against one of the most important insect pests of Southeast Asia that plagues rice cultivation: **The brown plant hopper** (BPH). Because management of BPH is not only based on pesticides, but also relates to proper use of fertilizer and cultural management, this pest is a good example of how IPM and good agricultural practice can work hand-in-hand to be effective and save costs at the same time.

Finally, aspects of **climate-smart rice cultivation** and the use of software to monitor carbon-footprints complement this brochure.

Special Feature

Climate-smart rice cultivation and Cool-Farm-Tool

(*Pages 8 and 9*)

Acknowledgements: *This brochure uses valuable information published by others, in particular references 6, 7, 8, 9, 10, and 13 (page 12). Sources for figures are indicated, or were provided by the authors. This publication contains original data on field demonstrations, which were kindly provided by Cuu Long Rice Research Institute (CLRRI) and the Plant Protection Department of the Ministry of Agriculture and Rural Development, Vietnam.*

Authors: Sieu Trinh & Thomas Jäkel

Hands-on Guidance on implementing Biocontrol and IPM

Inside this issue:

The rice field environment: Why so many pests & diseases?

The stable **traditional rice ecosystem** with co-evolved pests that developed over millennia was dramatically **changed in the 1960s** when **high-yielding rice varieties** (HYV), year-round irrigation, and heavy pesticide and fertilizer usage became widespread in Asia.

It opened up for **evolutionary changes and adaptations of rice pests** to the new situation. Until today, these relationships (i.e., causes and effects) are not fully understood. Among the **insect pests** that benefited most were those mainly feeding on rice, such as **stem borers**, **leafhoppers**, **planthoppers**, and **leaf folders**. Large-scale attempts in the Philippines to grow four irrigated crops in a year failed due to extreme pest attack, mainly brown planthopper (BPH) and rats. Pest problems get worse once one moves from dryland (rainfed) rice to irrigated wetland areas.

As the use of HYV was associated with recommendations of 3-4 insecticide applications per season, **high-input usage** was later found to be **responsible for resurgence of pests**, demonstrating the importance of **natural enemies**. Leafhoppers and planthoppers were minor pests before introduction of HYV (when, for instance, stem borers were dominating), and can be maintained at that status if insecticide usage is reduced or avoided, resistant varieties planted, and nitrogen fertilizer used judiciously .

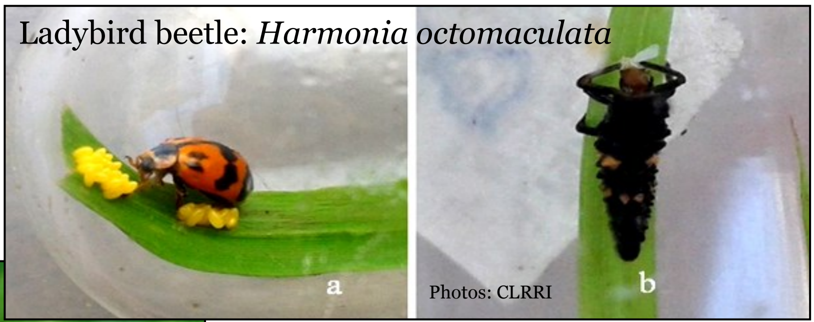
Nitrogen is well known to have strong effects both on **rice blast** and on rice yield. Intensification of rice production has had dramatic impacts on increasing rice blast and **sheath blight**. This also relates to **higher plant densities**, which can be associated with **increased fungal disease**.

The importance of **rodents** is often underrated relative to insect pests, although episodic outbreaks **can wipe out the entire harvest** if preventive measures are not taken seriously. Similar to certain insect pests, rats are well adapted to irrigation practices, with ***Bandicota*** spp. dominating in India and ***Rattus*** spp. in Southeast Asia.

Asian countries are slowly moving toward **direct seeding of rice** in response to the labor and water scarcity and increased production costs. Direct-seeded systems have several advantages over transplanted rice; however, **weeds**, including **weedy rice**, are the major problem in these systems. Weedy rice infestation is one of the most serious problems that growers encounter, because of the morphological and physiological similarities of weedy rice to cultivated rice and the absence of standing water at the time of crop emergence. In the absence of selective herbicides, **cultural weed management strategies** may help reduce the problem of weedy rice

Hence, although this leaflet mainly focuses on insect pests of rice, it is important for the practitioner and farmer to acknowledge that there exist other threats to rice cultivation that have to be envisaged, best in a preventative manner.

NATURAL ENEMIES OF INSECT PESTS IN RICE


Ladybird beetle: *Harmonia octomaculata*
a b Photos: CLRRI

Natural enemies play **key role in management of rice insect pests**, especially brown planthopper. In healthy, irrigated rice agroecosystem, beneficial predator and parasitoid insects are so abundant, that they can effectively control development of most of the insect pests.


Photo: CLRRI

A wide variety of **beneficials** naturally feeds on BPH and keep their population in control. This includes certain **spiders** and **mirid bugs** (e.g., *Cyrtorhinus lividipennis*), which are the most important natural enemies. Other species are also shown on this page.


Spider: *Argiope catenulata*
Photo: CLRRI

Unfortunately, under current rice farming conditions, farmers apply too many **broad-spectrum insecticides** at often higher than necessary concentrations. This can reduce populations of natural enemies dramatically. For instance, after spraying of **pyretroids** even low levels of residues on crops and other plants may prevent full recovery of natural enemy populations for months, if not longer, depending on the concentrations applied. Other broad-spectrum insecticides to be avoided include certain organophosphates and macrocyclic lactones like Abamectin. Although Abamectin is of biological origin (in some countries classified as bio-pesticide), its **broad-spectrum property is not compatible with protection of natural enemies**.


Mirid bug next to young BPH
Photo: IRRI

As a result, pest insects like BPH benefit from this situation, as they can built up **resistance to pesticides** fast. Once they develop in masses, we usually can observe the typical result in the rice field: large extents of damage in form of '**hopper burn**' (see image of front cover).


Lycosa spider

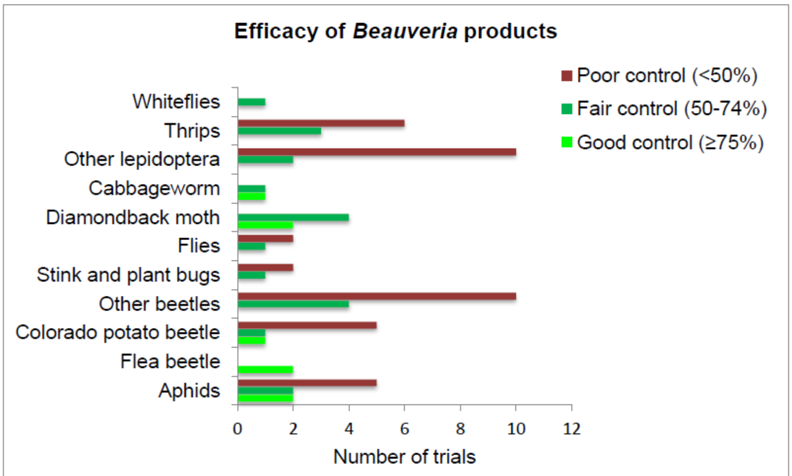

Ladybird beetle: *Micraspis discolor*
a b Photos: CLRRI

Biological control of insects using entomopathogenic fungi

The species of entomopathogenic fungi discussed here belong to the ascomycete group. ***Beauveria*** is a cosmopolitan genus of arthropod pathogens that includes the agronomically important species, ***B. bassiana*** and ***B. brongniartii***, which are used as mycoinsecticides for the biological control of pest insects. Both species have been linked developmentally and genetically to *Cordyceps* species.

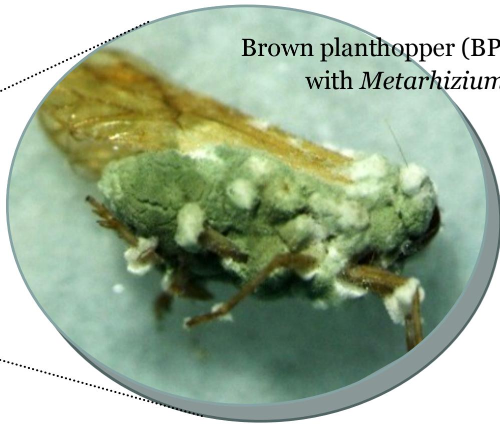
The genus ***Metarhizium*** is composed of fungi that generally are **greenish** when proliferating on the corpses of their arthropod hosts or in culture. They frequently are isolated from soils, parasitize a broad range of insect species and found throughout the tropics and temperate regions.

In **ASEAN,** *Metarhizium* agents were registered in Malaysia and Vietnam for control of BPH, rhinoceros beetle, termites, and others (see **ASEAN Biocontrol Database**). Products based on *Beauveria bassiana* are available in Cambodia, Indonesia, Philippines, and Vietnam, against target pests such as BPH, aphids, thrips, whitefly, bollworm, mirid bugs, termites, mosquitos, and various beetles including coffee berry borer.



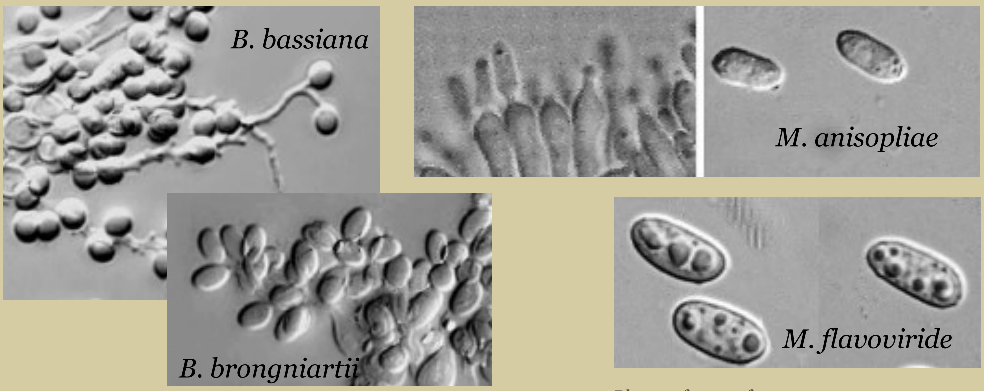
Adapted from *ref. 6*

For **application of entomopathogenic fungi** it is important to consider that **effectiveness** is often **strain** and **target-pest specific**. For instance, effectiveness of *Beauveria bassiana* (see graph above) depends on the strain or isolate used: while strain 1 may be effective against thrips, strain 2 may be not. Similary, strain 1 may control diamondback moth well, but not other lepidoptera. Commercial products of high quality come along with clear recommendations which pest species the fungal product can control.



Brown planthopper (BPH) infected with *Metarhizium anisopliae*

Beauveria and *Metarhizium* under the microscope



Photos: from *ref. 15*

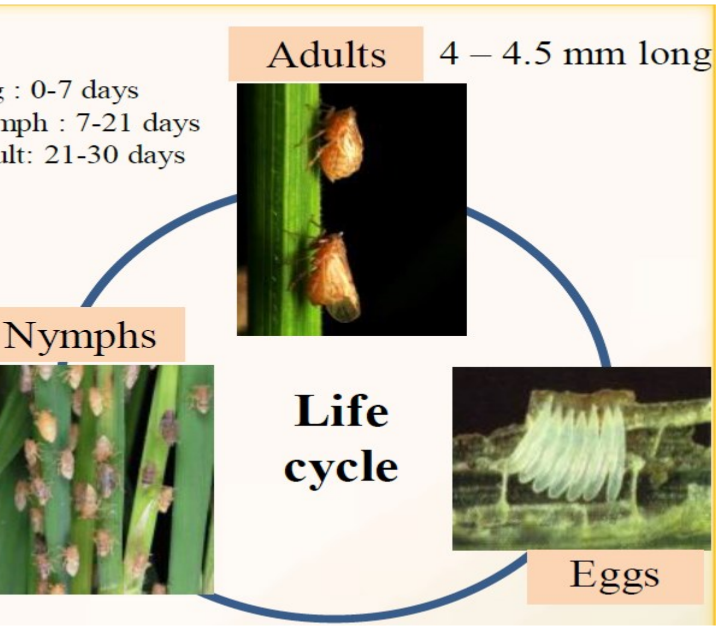
Photos: from *ref. 4*

Shown are the insect-infective stages: **spores** (conidia) and spore-forming cells of commonly used ***Beauveria*** spp. and ***Metarhizium*** spp. in commercial plant protection products. For each genus the same magnification is used.

Management of Brown Planthopper (BPH) using *Metarhizium anisopliae* and other fungi

The Brown Planthopper (BPH), *Nilaparvata lugens*, is one of the major rice insect pests responsible for, at times, huge economic losses. **Overuse of synthetic pesticides** has led to resistance develepement and is responsible for resurgence of BPH populations, mainly due to **killing off natural enemies** and **sprayings not reaching the eggs**, which females lay inside the leaf sheath.

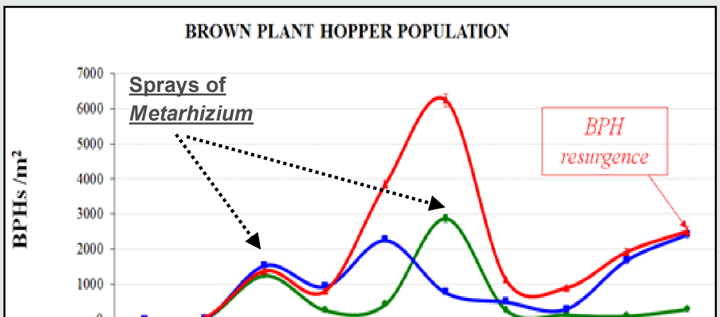
Biological control using *Metarhizium* spp. or *Beauveria* spp. is based on the principle that once BPH becomes infected, **infection spreads naturally** by contact to other individuals and their offspring, thereby killing BPH and **reducing the population over longer periods**. Because this is a different mode of action compared to synthetic pesticides, management by biocontrol follows a different approach.



ife cycle of Brown Planthopper (BPH)

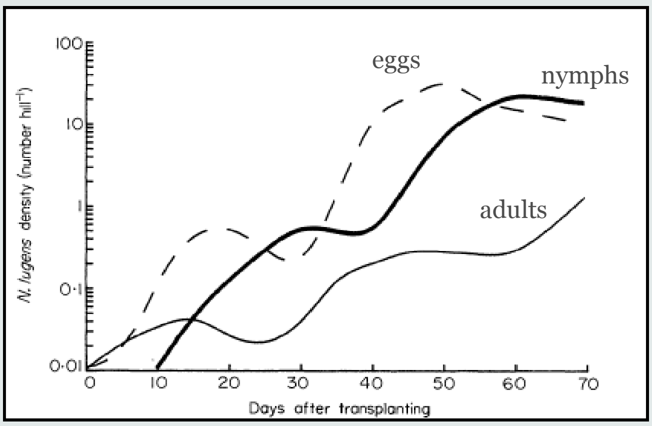
First, before spraying of fungal biocontrol preparations in rice, **natural enemies** (page 3) need to be protected beforehand by **not applying broad-spectrum pesticides within the first 40 days** after sowing or transplanting of rice. If adult BPH immigrate into the rice field within this period, this measure alone will most likely keep them in check as natural enemy populations will build up on this food source. So, **don't spray the immigrants**. Second, biocontrol application should start, when a certain **threshold of BPH nymphs** (larval stages) is reached. Good experiences in **broadcasted rice** have been made with **3 BPH per tiller** (or about 1000 BPH per m²). A **threshold for transplanted rice is about 100 nymphs or more per hill**. In an uncontrolled situation, BPH populations will typically show 2 or more development peaks (see figure below right), until the rice field may be completely damaged. Application of suitable strains of *Metarhizium anisopliae* and *Beauveria bassiana* at this threshold can **prevent BPH population surges** and also **resurgence** at a later stage of the growing period (see figure below left). Usually, **one or two applications per season are sufficient**.

Besides BPH, suitable *Metarhizium anisopliae* and *Beauveria bassiana* strains also can control **rice bugs** (*Leptocorisa* spp.; threshold: 10 insects per m²), which usually appear as a **late season pest**. Spraying the fungi has no effect on MRLs (Maximum Residue Limits), thus, allowing farmers to implement pest control even shortly before harvest. There are also reports that fungal biocontrol significantly reduced **leaf folder** populations during the late rice growing stage.



	20DAS	28DAS	37DAS	46DAS	53DAS	60DAS	67DAS	74DAS	81DAS	88DAS
BCA	5	24	1251	259	428	2872	269	131	96	287
Control I	8	19	1540	932	2251	763	499	300	1680	2415
Control II	9	53	1392	817	3851	6245	1129	903	1923	2512

Population dynamics of BPH treated with *Metarhizium anisopliae* (green) compared with use of synthetic pesticides (blue, red)



Population dynamics of BPH in an untreated, standard outbreak situation (simulation) (from *ref. 8*)

How to apply insect-pathogenic fungi?

Unlike synthetic insecticides, **fungal biocontrol agents are living agents.** Therefore, application needs to take care of this fact to achieve the best effectiveness.

Metarhizium spp. and *Beauveria* spp. can be sprayed directly to the crop, similar to any contact insecticide. The spray should contact the pest directly to be effective. In case of **BPH**, they normally dwell **at the base of rice plant**; while rice bugs usually resides on rice flowers.

Commercial products may formulate spores into **wettable powder**, so that farmers can dilute and use it directly with water. However, sometimes it may be better to add 'sticker' or 'spreader' to the spray suspension, as recommended by some producers. Whatever the product, it is important that the powder does **not form clumps** that settle at the bottom and **clog the sprayer nozzle**. **Powder formulations** should be **stored dry and cool to extend shelf life**.

Spraying equipment is crucial for success. Unfortunately, variable cone nozzles are used increasingly, which are almost impossible to calibrate for fungal spores. **Large droplets should be avoided** (they run off leaves), while smaller droplets should be checked before spraying whether they contain sufficient fungal spores (e.g., if possible using a microcope). If there is **lack of effectiveness**, spraying equipment should be considered first.

Preparing and spraying Metarhizium spp.

Examples of application rates (No. spores or colony-forming units [CFU] **per ha**) for *Metarhizium* (M) and *Beauveria* (B) (e.g., *ref. 1, 9, 14*)

5×10^{12}	Philippines (M)
6×10^{12}	Vietnam (M, B)
7.5×10^{12}	Korea (M, B)
2.5×10^{11} (CFU)	India (M)
5×10^{12} (CFU)	Thailand (M)

Do not mix fungal spores with synthetic pesticides, in particular fungicide and antibiotics.

Temperature and humidity are important factors for proper use fungal preparations. Application should be made **in the afternoon** (about 3-4 PM), when it gets cooler (and possibly more humid). Spraying *Metharizium* on BPH nymphs **at the base of rice plants in an irrigated field** provides optimum conditions with regard to humidity. Note, spores need to be stored dry, but require high humidity to germinate (about 15 hours) and attack BPH. However, if it rains after spraying, re-apply.

Action thresholds: see page 5; note: BPH populations cannot be eradicated, they can be controlled only.

What else to do against BPH?

- Use resistant rice varieties that can be rotated
- Allow for a fallow period between consecutive rice crops
- Application of organic fertilizers; overuse of nitrogen promotes BPH development
- Allow vegetation on bunds to provide habitat for natural enemies
- Grow a non-rice crop in the dry season

Economics of *BPH* and *leaf folder* control: Case studies in the Mekong Delta of Vietnam

Utilizing BCA in rice is not only about protecting natural enemies, but also **saving costs** and **reducing yield losses** by better protection.

In field demonstrations conducted by ASEAN SAS in collaboration with the **Cuu Long Rice Research Institute** (**CLRRI**) in the Mekong delta in Vietnam, use of locally produced *Metarhizium anisopliae* (trade name: '**Ometar**') helped to reduce pesticide input costs by 19%-41%, which translated into an overall reduction of farm expenses by 3% to 17%. Reduction was due to **better protection** and **fewer pesticide applications** in comparison with farmers' practice of using synthetic insecticides. For instance, application of *Metarhizium* reduced applications from 1-3 sprays against BPH and 2-5 sprays against **leaffolder** down to 1-2 sprays and 1-3 sprays per season, respectively.

The **table** below illustrates the **economic analysis** of the four field demonstrations of 'Ometar' that were conducted in the provinces Dong Thap (communities Binh Thanh, Lap Vo [demo 1] and My Dong, Thap Moi [demo 2]) and Kien Giang (communities Thanh Dong B, Tan Hiep [demo 3] and My Lam, Hon Dat [demo 4]) during October 2015 to March 2016. Input costs, revenue, and gross margin were expressed in US$ per ton of crop to be comparable with previous analyses in our publications.

Compared to common farmers' practice, all four demonstrations of 'Ometar' produced **higher gross margins**, with increases ranging from 9% (demo 4) to an impressive 21% (demo 3) for rice farming conditions.

'Ometar' demonstration: Farmer-Field-Day in Kien Giang province, Vietnam.

Dead BPH infected with *Metarhizium anisopliae* in the rice field.

Input Costs and Gross Margin of BPH Control

(Examples from Vietnam extrapolated to 1 ha)

M = *Metarhizium*; F = Farmer's practice

Item	Irrigated Rice (*Demo 1*)		Irrigated Rice (*Demo 2*)		Irrigated Rice (*Demo 3*)		Irrigated Rice (*Demo 4*)	
Productivity (t/ha)	**(M) 7.62**	**(F) 7.46**	**(M) 6.92**	**(F) 7.10**	**(M) 8.10**	**(F) 7.16**	**(M) 8.46**	**(F) 8.10**
Inputs (Costs) (US$/t)	**79.8**	**92.5**	**85.9**	**100.7**	**75.8**	**108.0**	**74.2**	**86.0**
* Labor etc.	* 32.6	32.6	* 32.0	31.1	* 26.9	30.4	* 30.1	31.7
* Fertilizer, seed, etc.	* 31.8	37.7	* 34.7	44.6	* 34.3	49.2	* 29.3	32.8
* Biocontrol or Pesticides	* 15.4	22.2	* 19.2	25.0	* 14.6	28.4	* 14.8	21.5
Revenue (US$/t)	**209.4**	**209.4**	**222.6**	**222.6**	**260.1**	**260.1**	**220.4**	**220.4**
Gross Margin (US$/t)	**129.6**	**116.9**	**136.7**	**121.9**	**184.3**	**152.1**	**146.2**	**134.4**

How good agricultural practice keeps BPH under control, farmers' costs low, and the climate cool

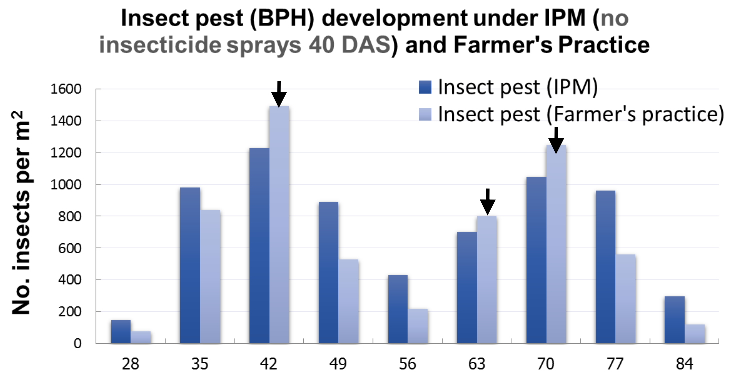
Shown here are experiences from Vietnam , where a **training module on rice IPM** targeting farmers was implemented by the **Sub-Plant Protection Department (SPPD) in Kien Giang province**, Plant Protection Station (PPS) An Bien, in cooperation with the People's Committee of **Dong Yen community**. Thirty farmers were trained on a demonstration site of 1.6 ha consisting of farmer's practice (control) and GAP-IPM plots in the summer season of 2016. The demo applied principles of the 'Three Reductions, Three Gains" campaign that Vietnam had launched in 2003 (*ref. 12*)

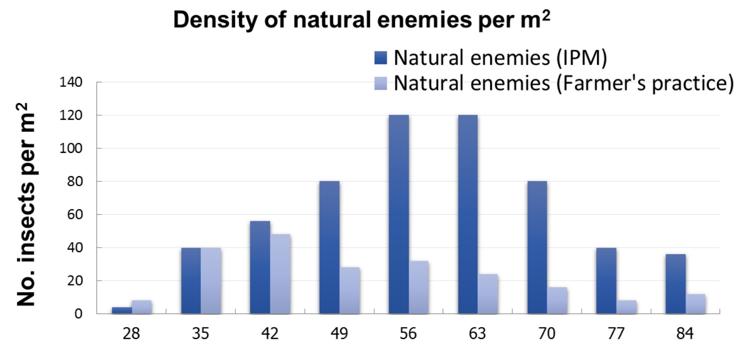
The **major IPM measure** emphasized was **no insecticide sprays during 40 days after sowing (DAS) rice**, the mainstay approach to protect natural enemies.

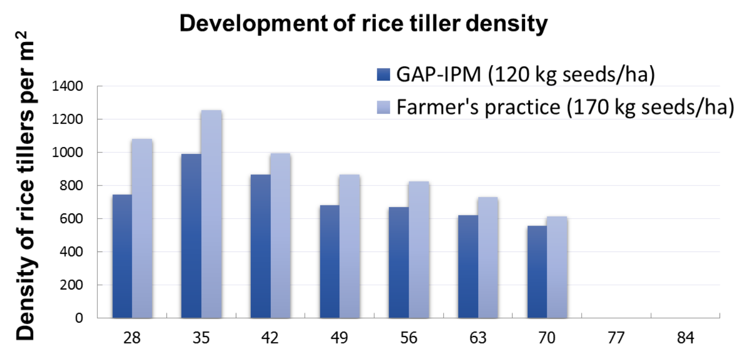
Principles of **good agricultural practice (GAP)** were implemented by **reducing use of fertilizer**, particularly nitrogen (N), which also contributes to development of insect pests like Brown Planthopper (BPH) if used excessively. **Seeding density** was also reduced significantly to demonstrate to farmers that good results can be achieved with less inputs.

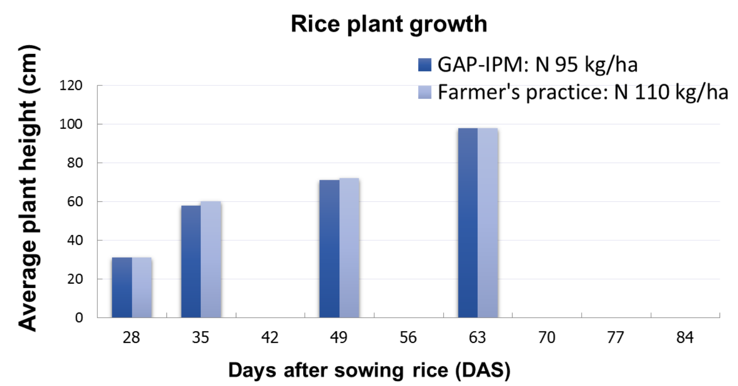
The **outcome of the field demonstration is shown on the right**. Clearly, not interfering in the rice field environment with synthetic insecticides protected natural enemies (spiders, mirid and water bugs), which, in turn, helped control BPH. Reduction of fertilizer and seeds was not detrimental to plant growth and density, respectively. Yield was the same in both scenarios (7.5 tons/ha), while average numbers of panicles per m² were slightly reduced in the GAP-IPM approach (555 versus 613).

Hence, a few **key measures** under GAP and IPM can help farmers reduce input costs (**gross margin was 9% higher** compared with farmer's practice) while enjoying good production results. Reduction of oil-based inputs like pesticides and fertilizer is an active **contribution to climate-smart agriculture** (CSA) in mitigating greenhouse gas emissions (*ref. 11*).









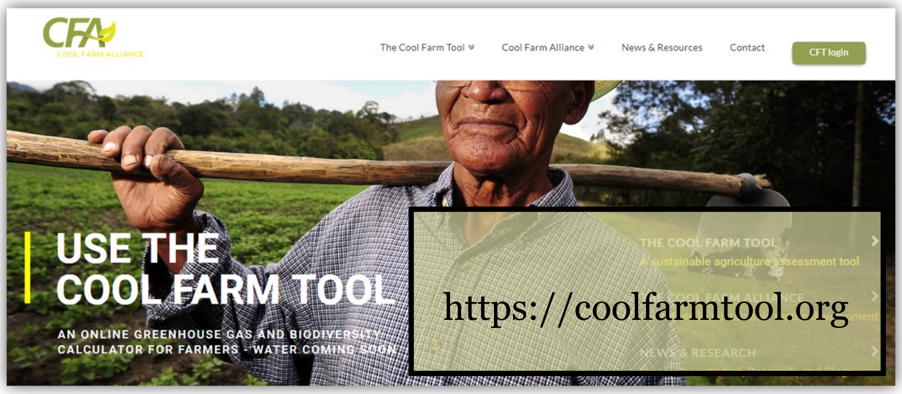
Graphs: **Comparison of GAP-IPM with farmer's practice in irrigated rice in Kien Giang province, Southern Vietnam.** Parameters shown are insect pest development (of BPH; insecticidal sprays in the farmer's practice plot are indicated by arrows), development of natural enemies, development of rice tiller density, and rice plant growth.

Using the Cool Farm Tool

The **Cool Farm Tool** is an **online greenhouse gas (GHG) and biodiversity calculator for farmers.** It is intended to help them choose management options that improve their environmental performance and to track and measure improvement over time. It covers virtually all crops and livestock globally (see reference 17 for review). Farmers can log in online and use the tool for free.

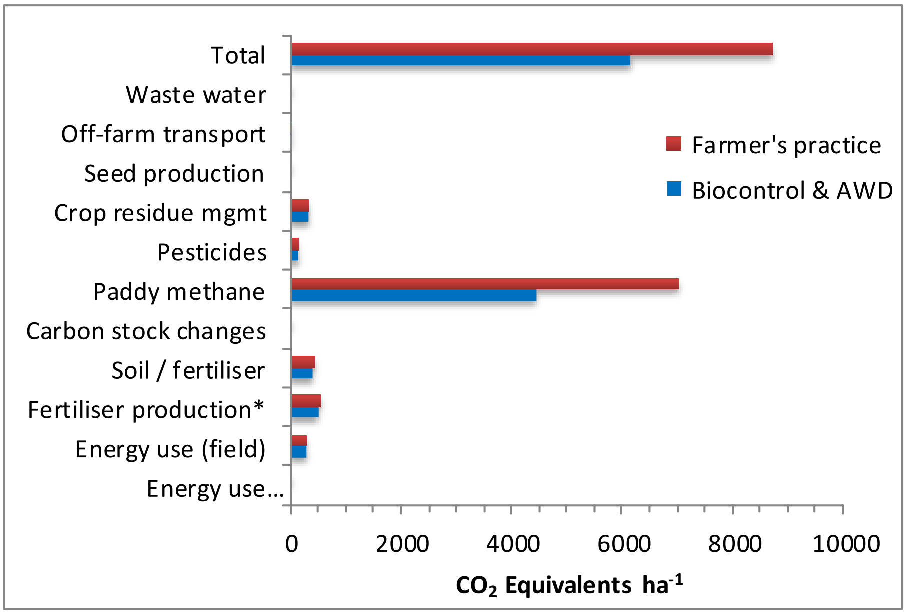
The Cool Farm Tool is broadly in line with international **standards** (e.g., the WRI GHG Protocol ISO, PAS2050, Carbon Trust, Life Cycle Analysis, etc.), complementing and enabling compliance with them.

It takes **10-15 minutes to get a rough estimate of a farm's carbon footprint** by entering information off the top of the head. To refine this estimate using information from farm records can take about 30-60 minutes. Often, the most time consuming part is looking up or estimating kWh and fuel for the year for the given crop from electricity and fuel bills. One may also wish to spend some time exploring options for reducing GHG emissions and making a plan.



Drop-down lists in the tool simplify data entry. Here is a list of questions for crop products that may require preparation in advance:

- Harvested yield and marketable yield product weights
- Growing area
- Fertilizer applications: type and rate
- Number of pesticide applications
- Energy use (kWh and fuel use)
- Optionally, transport: mode, weight of product and distance
- For livestock, calculations are built from herd size, manure management, feed and energy use.



With regard to the **field demonstration of *Metarhizium anisopliae* (Ometar) against BPH in Vietnam** we have calculated here the **GHG emissions** based on the Cool Farm Tool. Not only was biocontrol used instead of synthetic pesticides, but water management followed the **AWD (Alternate Wetting and Drying)** method: here, one drying phase was included. Cool Farm Tool discriminates between continuous flooding and single or multiple drying phases. For **pesticide application** Cool Farm Tool applies a validated standard value, which means that the same value is assigned to biocontrol and synthetic pesticides. Therefore, differences in pest management can become visible only in terms of numbers of applications.

A **comparison of GHG emissions of biocontrol and farmer's practice** (see graph) shows that biocontrol together with improved water management produced less emissions (CO_2 equivalents ha^{-1}) compared to farmer's practice (use of synthetic pesticides and continuous flooding). However, water management was of major influence on methane emissions in the rice field, while fertilizer and pesticide inputs contributed less. However, this situation can be different in other crops, where synthetic inputs may contribute to a higher degree to GHG.

Farmer-based production of insect-pathogenic fungi

Since 1995, the Biological Control Department of **Cuu Long Rice Research Institute (CLRRI)** in **Vietnam** has been collecting and isolating entomopathogenic fungi in the Mekong Delta to select an appropriate agent for the pest control. A bio-insecticide developed from ***Metarhizium anisopliae*** **isolate OM2-B** was registered by the institute under the trade name '**Ometar**', which was approved to use for controlling brown planthopper, rice bug, and coconut beetle.

Since its registration, 'Ometar' was introduced to farmers in several ways and has shown positive impacts in controlling insect pests and improving farmers' economic situation. **On-farm** or **household level production** of *Metarhizium anisopliae* has been one approach to disseminate the technology among farmers: CLRRI offers training courses for local technicians and farmers.

Training of local technicians and farmers in "quick green fungi production" at CLRRI

In a similar manner, the provincial branch in Chainat of the **Department of Agriculture and Extension (DOAE)** of **Thailand** promotes technology transfer to farmers. Here, the main **biocontrol agent for brown planthopper** is ***Beauveria bassiana***, of which stock is produced at the provincial government station and then disseminated to local farmers. Some of these farmers act as **small-scale producers**, who purchased some basic tools for producing the fungus, such as a sterile cabinet and a simple autoclave to sterilize the substrate for growing *Beauveria*.

Insect-pathogenic fungi can be easily **grown on substrates like maize or rice**. This business provides additional income to farmers. However, it is important to **avoid contamination** with unwanted fungi. This is where a research institute or government laboratory needs to come into play: **identity and quality of the strain or isolate** under use **has to be monitored and maintained**. Farmers are not in the position to do that over longer periods of time.

Rice is still being transplanted in Chainat province, Central Thailand

ASEAN SAS supported CLRRI in farmer trainings on the mass production of *Metarhizium anisopliae*, including education in the basic parameters presented in this leaflet like insect control efficacy, impact on natural enemies and environment, and farm economics.

A **mass-production course** typically requires about three days, while quantities produced can serve a farm household for a season or longer. Within three days, participants produced 450 bags containing fungal mycelia and spores (500 gram per bag), while 407 bags had good quality and the contamination rate was relatively low (9.5%). Harvested *Metarhizium anisopliae* spores were of good quality (2,5 x 10^9 CFU per gram). If one compares this with the application rates listed on page 6, **between 100 gram and 2 kg of fungal produce would be required to treat one ha of rice field**.

Some images on the opposite page illustrate farmer-based production and the tools required for it.

Farmer-based mass production of *Beauveria bassiana* supported by Department of Agricultural Extension (DOAE) in Chainat province, Thailand


Inoculation of substrate with fungi


Incubation of substrate (here: maize)


Sterilization of substrate


Fungal growth shortly before harvest (*Beauveria* = white)


Farmer's shop

Farmer-based mass production of *Metarhizium anisopliae* supported by Cuu Long Rice Research Institute (CLRRI) in the Mekong Delta, Vietnam


Tools for production: sterilization pot; fungal culture stock; substrate, here: rice; clean cabinet for inoculation of substrate


Fungal growth: white = before incubation, green = *Metarhizium anisopliae* after incubation

50 Department of Agriculture, 4th Floor, Sitthiporn Building, Phaholyothin Road, Ladyao, Chatuchak, Bangkok 10900

http://www.asean-agrifood.org

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