# Rice-Fish Farming Manual

**FishAdapt Project**




Food and Agriculture
Organization of the
United Nations

Food and Agriculture Organization of the United Nations

# Contents

## Preparation of this document

In view of the impacts that climate change is going to have in the world and in particular on food security and vulnerability, the Food and Agriculture Organisation of the United Nations has launched a series of initiatives targeting the awareness, the capacity building of both ministerial officers, development agents and communities on the sustainable management of natural resources.

Climate smart approaches are fundamental to reduce the footprint of modern production systems, including agriculture and aquaculture, and improvements are needed to increase the resiliency of all those communities that are at the frontline for the effects of the climate change.

On this regard FAO prepared a comprehensive manual on rice-fish farming to propose strategies in food production that prioritize integration, reuse of wastes, biological management, greenhouse gases abatement and low fuel consumption in order to guarantee robust and sustainable growth.

The present manual was prepared by Dr. Edoardo Pantanella aquaculture consultant and climate change specialist, supervised by the FAO FishAdapt Team Leader Mr. Jose Parajua and reviewed by the FAO national aquaculture expert Daw Moe Kyi Phyu and the national climate change adaptation - disaster risk management expert U Aung Tun Oo.

The Rice-Fish Farming Manual was developed for the Myanmar FishAdapt Project (MYA/020/LDF), which was financially supported by the Global Environment Facility (GEF), the Food and Agriculture Organization (FAO), the Livelihoods and Food Security Trust Fund (LIFT), Japan (JICA), Worldfish, the Myanmar Department of Fisheries (MoALI) and the Myanmar Fisheries Federation (MFF).

Food and Agriculture Organization of the United Nations


## Abstract

This manual seeks to provide a comprehensive technical knowledge on all the aspects related to rice-fish productions, and to showcase strategies that can be used to promote polyculture in traditional rice farming systems that make use of chemicals inputs.

Different factors that influence both rice and fish culture are presented, together with the advantages and disadvantages of fish culture on rice under traditional systems. The section is followed by a detailed description of the different systems that can developed, which includes concurrent and compartmentalized systems, polyculture with other plants and animal species, and rotational culture. The manual highlights the possibility to combine fish culture even with conventional rice farming, which makes use of chemical inputs. In the same manner it promotes strategies that need to be adopted to make rice culture more greenhouse-gas friendly. The following sections give further insights on the sizing and ratios of the systems, on the different choices of plants and fish, and detailed descriptions of the management of the systems with step-by-step explanations of the tasks to be performed.

The final part gives a deep overview of the integrated pest and disease management and provides tools for the agronomic and biologic protection that can be used to support rice farming under a more natural and low/no chemical management.

This manual aims to give to governmental and not governmental organizations a basis for developing or adapt rice-fish to different contexts and managements, and to provide knowledge in communities on the different strategies that can be used to improve productivity under more sustainable and climate friendly approaches.

## Abbreviations/symbols

| | |
|---|---|
| BW | Body weight |
| $CH_4$ | Methane |
| DO | Dissolved oxygen |
| EC | Electrical conductivity |
| GHG | Greenhouse gases |
| IPM/IPDM | Integrated pest management/integrated pest and disease management |
| MT | metric ton |
| $N_2O$ | Nitrous oxyde |
| $NH_3$ | Ammonia |
| $NO_3$ | Nitrate |
| $P_2O_5$ | Phosphorus pentoxide |
| pH | level of acidity or alkalinity of the water, soil |
| SRI | System for Rice Intensification |
| TSP | Triple super phosphate |

## Glossary

| | |
|---|---|
| Accumulation | Gradual inclusion in the body of chemicals, such as pesticides |
| Aerobic | A state of presence of oxygen |
| Allochemicals | Plants by-products that serve as defence against insects |
| Ammonia | Compound of nitrogen, present in fertilizers but also excreted by fish |
| Anaerobic | A state of absence of oxygen |
| Anoxic | Anaerobic |
| Antagonists | Insects that oppose to pests by predating or parasitizing their egg/larvae |
| Antibiosis | Antagonistic association of two organisms in which one is adversely affected |
| Autotrophic | An organism capable to produce its own food by using light and inorganic elements. |
| Bioturbation | Disturbance of sediment materials by living organisms |
| Carnivorous | Animal feeding on other animals |
| Carrying capacity | The number of living organisms that a pond or water body can support without environmental degradation |
| Chitin | An organic component constituting the skin of the insects |
| Chlorosis | Anomalous discoloration of plants due to nutrient deficiency |
| Cyanobacteria | A type of bacteria that is capable of photosynthesis |
| Decoupled | Separated systems. Refer to integrated aquaculture systems where fish grow separated by the plants |
| Diapause | A time period of suspended growth of insects following unfavourable conditions. |
| Eutrophic | An environment rich in nutrients that supports a dense plant population |
| Gape | An opening, mouth |
| Herbivorous | Animal feeding on grasses |
| Heterotrophic | An organism not able to produce its own food but needs to procure it from other organisms |
| Hill | The cluster of shoots originating from the initial seedlings |
| Humus | The organic constituent of the soil, formed by the decomposition of vegetable materials by microorganisms |
| Macrophyte | An aquatic plant growing in or near water bodies. |
| Market-size | Desired weight/size by market customers |
| Molting | Is the process of producing a new cuticle and the subsequent shedding of the old cuticle in insects |
| Monophagous | Animal or insect eating only one kind of food |
| Nitrate | Oxidized form of nitrogen |
| Oligotrophic | Environment that offers very low levels of nutrients |
| Omnivorous | An animal feeding on any source of food |

| | |
|---|---|
| Persistence | The lifetime of a chemical compound before being degraded |
| Phytoplankton | Microscopic marine algae |
| Plankton | The sum of microscopic organisms, such as microalgae or phytoplankton, microscopic animals or zooplankton, present in the water that constitutes the base for the nutrition for planktivorous fish. |
| Planktivorous | Animal feeding on plankton |
| Primary productivity | production of organic compounds by photosynthetic organisms |
| Puddling | Tillage of rice fields in the presence of water |
| Ratooning | Regrowth of a plant that has been harvested |
| Ridge | A continuous elevated crest of soil prepared for plant cultivation |
| Sclerotia | A dark body of fungi in their resting phase capable to stay dormant for a long period of time. It is made of hyphal threads. |
| Seedling | A young plant originating from a seed |
| Spinning | excessive plant elongation due to excess of nitrogen or competition for light |
| Stubble | The cut stalks of rice plants left sticking out of the ground after the rice grains are harvested |
| Table-size | portion side to be eaten by a single person |
| Tillage | The land preparation for crops |
| Tillering | The formation of the shoots originating from a single parent seedling |
| Top dressing | fertilization that is done when the crop is already established to boost growth |
| Vectors | Agent (insect) which carries and transmits a pathogen |
| Withdrawal period | Period of time that must be observed between a chemical treatment on the plant and the harvest |
| Zooplankton | Small or microscopic heterotrophic organisms that drift with water currents |

## 1. Introduction

Rice-Fish farming (RF) has been practiced for thousands of years in Asia. Farmers used to entrap in the paddy fields numerous aquatic species and to hold them in a polyculture. Although this farming practice was set aside with the advent of the green revolution and the industrial intensification of agriculture, rice-fish has continued to be used in some regions due its capacity to provide livelihood in depressed areas or farming opportunities for niche markets. However, with the progressive reductions in yields and profit margins, a great deal of farmers in many areas of the South East Asia have started to consider again this type of integrated production.

Rice-fish systems include many types of species from different origins (capture, hatchery), agronomic managements (polyculture at the same time, rotational, decoupled), and different intensities to meet the needs for household consumption or market sale.

Rice-fish brings many benefits to farmers. It increases land and water productivity, raises yields and incomes, improves nutrition and livelihood opportunities with a wide range of products and aquatic animals, and reduces vulnerability by differentiating productions.

With nearly 20 million of acres Myanmar is a big producer of rice and almost 5 million of households base their livelihoods on staple farming.

The production of aquatic animals from rice-fish depends on the degree of intensification. It was seen varying from the 120 kg/acre in the Philippines to 1.2 MT/acre in Bangladesh, China and Indonesia. FAO could verify that there is on average an increase of rice output of 0.2 MT/acre in RF systems. Therefore, given the polyculture of fish and staples as well as the higher productivity of rice, the expected revenues and profits are almost double.

In the case of Myanmar pilot rice-fish farms in the Ayeyarwady delta have demonstrated that consumption of fish at household levels have almost doubled, raising to nearly 5 fish meals a week. However current stringent land policies restrict the use of paddy land for productions other than rice crops, therefore any shift to alternative or complementary crops should undergo very long processes to get necessary authorizations.

Rice-fish systems, with an average loss of 10-15% of paddy area allocated for fish recovery areas can guarantee higher rice productions than those obtainable by paddy areas alone. This increase of productivity is due to the beneficial support given by fish that consume pests, weeds and facilitate a minimal fertilization of the crop with their faeces. Given the positive results the Union Minister of agriculture instructed the concerned departments to disseminate the technique since mid-2018, also in view of the benefits obtainable by increased fish outputs to compensate for the decline of inland fisheries and to integrate with alternative crops the production of rice.

The choice of the rice-fish depends on the local eco-climatic conditions and pest-disease occurrences, since any system has to be designed to adapt the needs of the farmers to local conditions. In the vision of climate change it is also important to consider the different climate-driven factors that could affect the agricultural productions in the present and in the future: drought, salinity inclusion, greenhouse gases emissions.

The current handbook seeks to provide some knowledge on the different rice-fish managements and at the same time provide strategies for climate change adaptation.

## 2. Rice-fish culture

The rice-fish farming requires good knowledge of the environmental and climatic characteristics of each location where production is going to be established. Like any type of polyculture it is in fact indispensable to consider the optimal needs for both fish and rice to maximize production. Therefore, the choice of fish species that match the local climate and the adaptation of paddy design and management to the specific production needs are very important. The choice of fish is equally important when there is the need to harvest both rice and fish at almost the same time (e.g. rainfed rice that does not allow for irrigation), or when fish can be farmed in the successive irrigated paddy instead. In the first case there is the need to use fast growing fish, while in the second the choice of animals should keep into account the resistance to possible stresses following the harvest and replanting: confinement of fish in the ditches during 1st crop harvest; higher temperatures in the flooded rice paddy following the transplant of the 2nd crop and the lack of plants' canopy to prevent water from overheating under the sun.

In growing fish in rice fields, there is the need to look at the physicochemical and biological characteristics of the hosting environments. The purpose is double: choose species of fish and prawns adapted for the culture; and adjust the rice fields and the operations to target optimal growth and high yields for both rice and fish. An aspect of interest is also the time. In combined cultures of rice and fish the average duration of rice crops is 100 – 150 days, but when the same fish batch is left growing further (either in fallow conditions or in a second rice crop) there would be some abrupt changes in the environmental and water parameters.

### 2.1 Factors influencing fish culture

#### *2.1.1 Water supply*

Water is the most important element to farm aquatic animals and there should be sufficient volumes to guarantee for a growth cycle of the fish. In general 1200 mm of rain a year is the minimal condition for farming and keep flooded an area for at least a crop cycle. Therefore plans should be put in action to secure that rain water is not lost by safely storing it in dams, ponds, canals, etc. However many other factors may affect the availability of the water, since temperatures, soil characteristics, and wind are factors that can increase its exhaustion due to evaporation or seepage.

#### *2.1.2 Temperatures and oxygen availability*

In traditional rice paddies the average depth ranges from 1 to 7 inches, which may represent an issue for the farming of bottom-loving aquatic animals. Having such shallow levels of water it is more likely that temperatures raise due to the higher accumulation of heat in water than in the air, which eventually can stress and kill the fish. Temperatures increase mainly for the lack of shading effect from the plants' canopy in addition to weather/sun radiation, season, latitude, altitude, and wind.

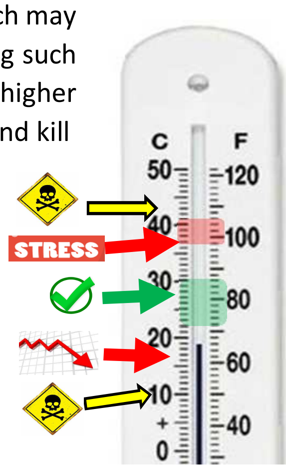


Fig. 1 Temperature ranges for tropical fish

In shallow waters temperatures can easily go up to 40°C or more, which severely limits the availability of dissolved oxygen in the water. Oxygen in fact is not only less soluble at higher temperatures, but it is also increasingly consumed by the aquatic animals and the organic matter/wastes in the paddy. On the contrary water can also host microalgae that help to recharge oxygen, however at night the net consumption of oxygen by these photosynthetic organisms can bring water to a depletion, particularly in the early hours of the morning before dawn. Such competition could eventually lead to anaerobic conditions particularly critical during in the rainy season, when the water level in the paddy is higher.

Rice production areas in are in general in the tropics or subtropics, where problems of low temperatures are almost inexistent. However in highlands or at higher latitudes the problem of cold water can be an issue particularly where the night temperatures reach 15°C

### *2.1.3 Water quality*

The presence of clayish soils and rain always bring many particles in suspension. Lack of transparency does not help to have a good photosynthesis, but in the case of paddy fields this does not apply due to the shallow conditions of the water that let the light penetrate to support some phytoplankton growth. Nevertheless the fish choice should also take into account of the predisposition of the soil to suspend particles, in this case carps and air breathing fish have some advantages.

Fig. 2 Water turbidity in a rice-fish trench

Fig. 3 Low productivity is common in saline water

Saline inclusion is particularly high in coastal and estuarine areas during the end of the dry season. In Bangladesh, India and Indonesia there are a few slightly-tolerant rice varieties that could cope with the salinity levels, although they are of lower yields than traditional types. Nevertheless salinity may shift the choice of aquatic animals from freshwater to brackish water species, such as mullet, Asian seabass, peneid shrimps or tilapia. Tilapia can in fact perfectly tolerate salinity of 10 ppt.

Both fertilizers and agrochemicals are particularly used in modern industrial crop productions. This severely limits the possibility to co-culture plants and aquatic animals, unless some compromises are achieved or a shift towards organic rice production is made. Presence of chemicals, if not killing the animals and the planktonic organisms, poses severe concerns about the safety of food, as they can get accumulated in animals' flesh. However the choice is on a case to case level, since areas that are environmentally less affected by problems of pest and diseases could more favourably use rice-fish in co-culture.

Addition of fertilizers, and in particular organic ones, can have a positive effect to the plants and to the aquatic ecosystem as their nutrients are also used to stimulate phytoplankton and zooplankton growth. However there is the need to consider the risks of overloading the paddy and thus create anaerobic conditions that can either kill the fish or create methane gas and hydrogen sulphide, the latter a toxic gas for fish that has smell of rotten eggs. This should bring farmers to prudentially manage the crops to avoid from one side any failure in nourishing the plants, but on the other side the abstention from any harm to the fish. Ideally manure should be added in dry conditions many weeks before the flooding of the paddy to let the organic matter mineralize. In rainy seasons it would be good to continuously add very small amounts of fertilizers to the plants. Ideally during the monsoon a shift from fertilizer to fish feed can be very advantageous, since fish would eat the feed, grow and fertilize the pond with their daily discharge of faeces and urine that are an excellent mix of fertilizer.

This smarter management of slowly giving fertilizers and to add manure/organic matter in dry conditions is ideal to avoid losses of nitrogen into the atmosphere caused by the lack of oxygen, but also to control of any gas emission affecting climate change, such as methane (from anaerobic decomposition of organic matter) and nitrous oxide (from anaerobic decomposition of nitrogen fertilizer).

Fig. 4 chemical fertilizers give immediate nutrients but can exploit the soil with high mineralization

Fig. 5 cattle manure give slower nutrients and make the soil fertile with organic matter

Rice production greatly affects climate change through emissions methane ($CH_4$) and nitrous oxide ($N_2O$) gases, which are 25 and 298 times more dangerous than carbon dioxide.

- Methane is produced from decomposing organic matter under water and no oxygen
- Nitrous oxide it produced by the anaerobic decomposition of nitrogen fertilizers

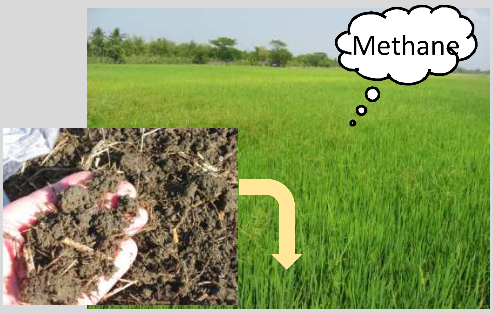



Fig. 6 Adding manure or organic matter into soil and then flood too soon creates the conditions to produce methane gas

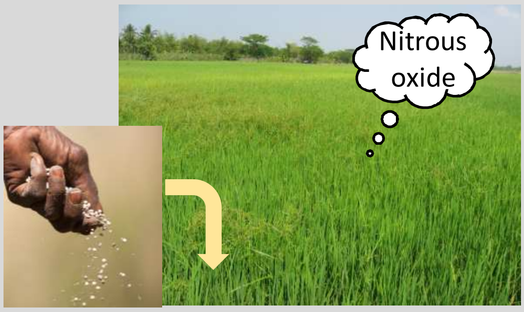



Fig. 7 Adding lots of nitrogen and then flood and dry cyclically creates the conditions to lose fertilizer in the form of nitrous oxide in the air

Manure or any organic matter needs to be left mineralize for some months into the soil to avoid anaerobic decomposition into methane. Ideally crop residues should be plough soon after harvest to get rid of pests and diseases and to leave sufficient time during the dry season to transform these organic wastes into humus. Fish in rice fields help to control organic wastes by eating them. In addition fish swimming help to re-suspend wastes accumulated at the bottom and to oxygenate them, which would avoid production of methane.

Addition of large amounts of nitrogen altogether is not an advantage since heavy rain or floods can quickly wash them away. The fertilization at the surface followed by flood and drain cycles, would expose the field to both aerobic (air) and anaerobic conditions that would eventually favour the rapid loss of nitrogen into the air by bacteria. A good strategy is to incorporate moderate quantities of slow releasing fertilizers into the soil during tillage/puddling so that the slow release of nutrients is quickly absorbed by roots and is not lost. Additional batches of nitrogen are broadcasted along the crop season. Manure is a good source of natural slow-release fertilizer to plants, but needs to be left mineralized before flood the rice field.

Ammonia is a waste product of the aquatic animals' digestion. Its accumulation in the pond could create dangerous situations leading to fish mortality, which is also increased by high water temperatures and high pH (above 7.5). Situations of high fish densities, excessive feeding (if feed is given), liming, and intense fertilization with ammonia, quick-release fertilizers or ammonium sulphate, could create dangerous conditions for fish.

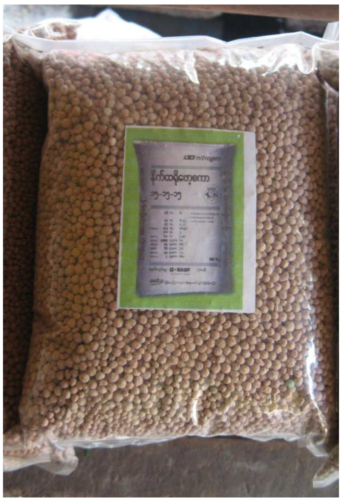


Fig. 8 Ammonia in fertilizers can harm the fish


Fig. 9 Chemical treatments against pests and diseases are dangerous for fish and for people who eat them

## 2.2 Factors influencing rice culture

### *2.2.1 Agronomic tasks*

Paddy need a good balance of nutrients to grow, which is guaranteed by correct fertilization and use of amendments (compost, manure) to maintain good organic matter into the soil. Nutrients however can also stimulate a large quantity of microalgae and aquatic plants that could be reach several MT per acre. Temperatures and the dryness conditions of the field could depress plankton productivity and in some cases even favour specific types of photosynthetic organisms, such as, cyanobacteria, whose growth seems to be stimulated by high phosphorus and higher pH. Cyanobacteria might not be a desired plankton due to the allegedly off-flavours procured in the fish when they are consumed.

Agronomic tasks, such as tillage, puddling and transplanting could also favour quick algal blooms due to the release in surface of nitrogen trapped into the soil. At the same time turbidity could also increase due to the resuspension of clay particles into the water.

Water management could vary depending on the location. Currently commercial rice varieties are shorter than traditional types that allow higher water levels for fish. On the other hand in rice-only systems the paddies should not necessarily be maintained flooded, since alternative techniques like *System for Rice Intensification* (SRI) can allegedly reach much higher productions by simply keeping the soil wet but not flooded to allow aerobic micro-organisms to ease the uptake of nutrients by plants.

## 2.3 Advantages and disadvantages of fish culture on rice

### *2.3.1 Advantages*

Rice plants, like any other agricultural crops, have to compete against the weeds that battle for nutrients, space and light. Eventually this type of rivalry can result in production losses that can reach 50%. Industrialized production make use of herbicides, however the practice may not be always successful and secondary control (mechanical, manual) is needed to eliminate resistant plants. Fish, on the other hand, target weeds and even phytoplankton as feed inputs, thus resulting in consistent reductions in losses of nutrients, which are made available to rice plants or can be mobilized back when fish defecate or urinate. Likewise benefits also come from the control of zooplankton and small invertebrates that feed on both algae and decaying organic matter (e.g. manure used to fertilize). Again this reduction of microscopic organisms contribute to support fish growth, but also to re-mobilize back to the plants the wastes of the fish.

At agronomic level the bioturbation on the bottom induced by the swimming of the fish helps to mobilize and to oxygenate the superficial layer of the soil and help accessing the phosphorus by the plants. A further control is also given by the benthic habit of some species that can graze organic matter at the bottom, which contributes to redistribution of nutrients across the area.

The feeding characteristics of certain fish helps to control snails and slugs that are commonly infesting many lowland areas with relevant damages on the crops. If paddies were not in production with fish the control could be guaranteed by terrestrial animals such as ducks that can be left roaming during the cultivation but also the fallow period. The agronomic control can also come into support of the elimination of these pests by cleaning vegetation on the banks, and liming the soil.

Another very important health contribution is the control of mosquito larvae that nurse in the water. This has a very important impact as would reduce the morbidity and mortality by malaria and dengue in infested area.

### *2.3.2 Disadvantages*

The combination of two different species in a single area always needs to find a compromise between the optimal needs of rice and those of fish, which can differ. Furthermore the need of any agronomic intervention on the rice could put in danger the fish for the presence of machineries, or the need to quickly level down the water to make some urgent treatments.

Modern rice varieties are mainly dwarf and precocious (short cycle), which not really meet the fish requirements for deeper paddies and longer crops. Dwarf varieties are preferred because they avoid that nutrients go to nourish unproductive parts of the plants or to make the plants more prone to fall to the ground in case of wind storms. Short cycles are preferred because they maximize the availability of water and somehow reduce the risk to have the crop exposed to potential threats.

As mentioned earlier paddies not necessarily need to be flooded all the time, since more modern techniques claim to be more productive under dry conditions (e.g. SRI). This has also important implications in climate smart agriculture because flooded paddies, if not managed cautiously in their nitrogen and organic matter loads, can bring to relevant emissions of very powerful greenhouse gases such as methane and nitrous oxide.

The construction of a system that holds fish with a sufficient level of water implies the raise of embankments that are much taller and labour-demanding than the traditional ones. In addition the farming of rice and fish during the dry season may be additionally disadvantageous due to the much bigger volumes of water that need to be abstracted to maintain fish mobility and compensate for the increased water evaporation.

Industrial scale rice culture is mainly based on the optimized use of fertilizers and chemicals to control weeds, pests and diseases. All these chemicals and part of the fertilizers (ammonia-based, if given in large quantities) are dangerous to the aquatic animals to the extent that rice farmers could be discouraged from adopting this polyculture in the fear losses or crop failures.

# 3. Rice-fish designs

## 3.1 Types of production systems

Different systems can be developed for rice and fish culture. In general the choice depends on the availability of water, fry, weather and climate throughout the year. The type of management, is also affected by the possible presence of pests and/or disease that may suggest to manage fish separately from the rice field in a permanent way or only when a treatment to the plants is needed.

The rice and fish can be:

- Concurrent, or cultivated at the same time and in the same area,
- Compartmentalized in two different areas where the fish can be permanently or temporarily separated to allow integrated pest and disease control that requires alternate periods of flood and dryness in the field, or to perform possible chemical treatments.
- Rotational culture where successions between rice and fish are done.

### *3.1.1 Concurrent systems*

The type of system see the fish and the rice farmed in the same field and during the same time. The fish swim around the plants and can move to/from their refuges that are made of deeper trenches, sump or small impoundments. Depending on the regions different layouts are possible. A simple trench can be dug either at one side or around of the paddy field. In both cases there is immediate control of the fish that can be reached for feeding operations. The trench running all around the rice area gives also some benefits in terms of space between the vegetation growing on the dikes and the rice plants, thus reducing some risks of pest migration.

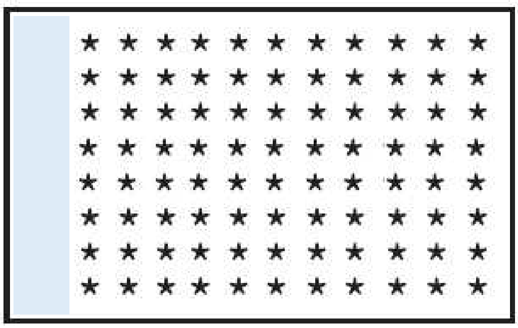


Fig. 10 Paddy with lateral trench

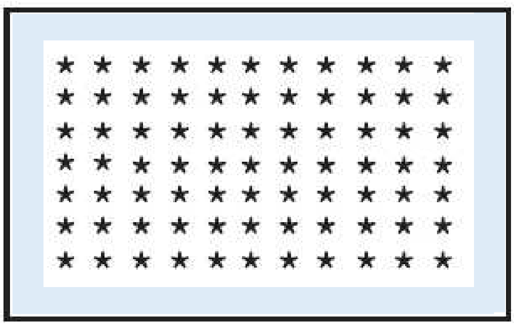


Fig.11 Trench running at the perimeter of paddy

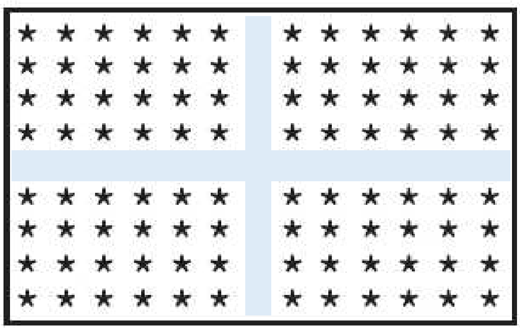


Fig. 12 Trenches create paddy sections

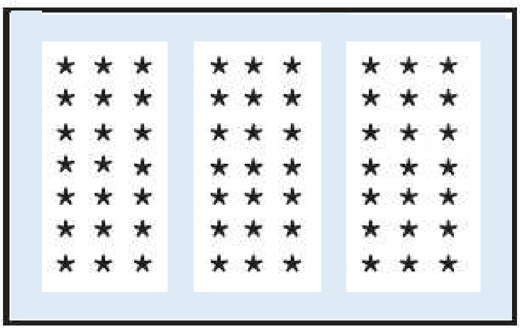


Fig.13 Three sections and perimeter layout

Alternative designs could take advantages of the slope of the land or meant to favour the movement of the fish to the maximum. Nevertheless fish and plants are always in close contact and there are no many options of alternative water management in case of treatments with pesticides.

Trenches for their nature are not very deep, (1-2 ft) therefore this type of design should consider the temperature extremes of the the location, as deeper water is needed in case of hot summers. One alternative option considers the use of deeper ponds instead. In some regions the pond is located at the centre of the rice field, but this layout may make it difficult to manage the animals for daily operations (e.g. feeding) or for partial harvest of fish if the rice plants are still growing.

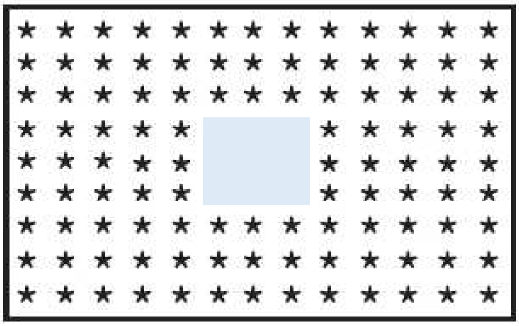


Fig.14 Small pond at the centre of a paddy

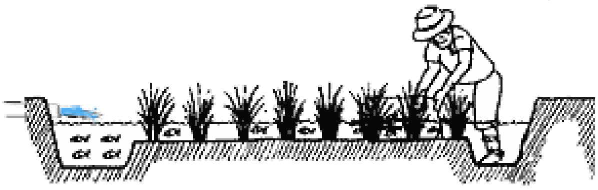


Fig. 15 A trench/pond located at the inlet favours a quick water supply and exchange to fish

On the other hand having the inlet of the rice-fish system pouring directly on the trench/pond (Fig. 15) makes the water management much easier when the refuge needs to be refilled with water, or when some water exchange is needed to improve the water quality for the fish.

Fig. 16 A large trench for fish

Fig. 17 Fish growing in the trench after harvest

Rice-fish in hilly or mountainous areas need to be developed on terraces with levelled land. In this case fish can roam around the plants and get back to their refuges where they can be eventually harvested. The choice of the refuge (trench, pit, small pond) depends on the land characteristics.

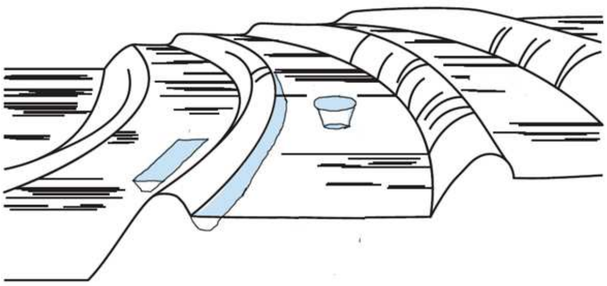


Fig. 20 Rice in terraces. Different refuges in shapes of pits, trenches or small ponds are possible

Fig. 21 Hill rice growing in terraces

Rice-fish in terraces is very advantageous as it compensates for the much lower yields achievable compared to lowland areas (-30/-50%). Such lower yields are due to the not favourable exposition to the sun and the much shorter water availability (lack of water streams uphill). If the rainy season is sufficiently abundant one variation could be seen in the use of the top terrace as a deeper fish pond that would serve as reservoir to supply water to the downhill terraces (compartmentalized system, see below), thus extending the season for a sufficient time to cultivate long-season rice varieties.

| **Concurrent rice-fish in the same land and time** | |
|---|---|
| **Advantages** | **Disadvantages** |
| • Easy construction<br>• Easy management<br>• Particularly suited for low-input farming<br>• Simple water management | • Rice and fish may need to be harvested at the same time if fish cannot get a refuge in deeper trenches.<br>• No easy management if there are pests and diseases, as lack of compartments may prevent to do the necessary treatments.<br>• System less flexible to IPDM by manipulating the water level, unless deeper refuges are made |

### *3.1.2 Compartmentalized systems*

In these systems rice and fish can be separated temporarily or permanently to perform the necessary agronomic tasks to the rice. Fish can be separated by rice field at the lowering of the water level and be cast away by closing the passages between the refuge and the rice field. Simple dikes can keep separated the fish and avoid water exchange with the rice field Fig. 22.

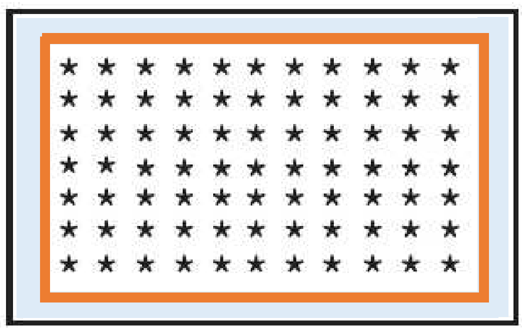


Fig. 22 Fish separated by small dikes when water level goes down

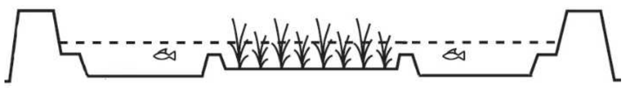


Fig. 23 Side view of the separation of fish and rice

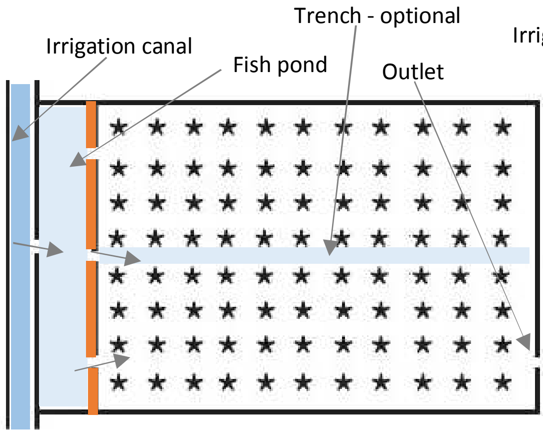



Fig. 24 Pond separated by dikes with closures

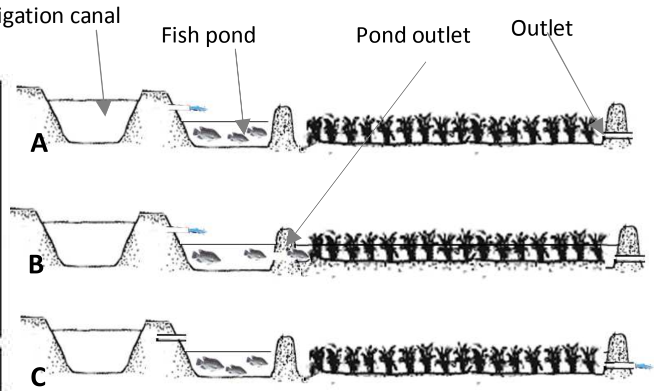



Fig. 25 Side view of the inlet pond serving the paddy

More advanced designs see the possibility to have a complete exclusion of fish when needed. Fish are hold in their refuge/pond directly supplied by water by the irrigation canals (Fig. 24). When rice field is flooded fish can roam around the plants, when water level goes down fish return to their pond and if passages are closed the rice field can be managed as an independent system for necessary treatments. A drainage at the rice field outlet helps to speed up the water removal in case of necessity (Fig. 25C).

| **Compartmentalized rice-fish systems in ponds/dikes** | |
|---|---|
| **Advantages** | **Disadvantages** |
| • Customized management of rice field, compatible with possible treatments on rice<br>• Fish management can be extended across two rice seasons/be permanent<br>• water management adjustable according to the needs<br>• compatible with SRI management (see following chapter) | • more earthwork to be done, thus more expensive<br>• dry rice more likely to be done only during dry season<br>• fish may need additional feed to grow<br>• water quality check needed in case of long permanence of fish in the pond |

Another compartmentalized system can be also a simple fish cage positioned in the irrigation canal or in an encroachment at the inlet of the paddy. In this case fish cannot roam around the rice area but are confined in the cage. In case of nursery this solution can be very effective as the cage prevents any predator to kill the fish. One partial disadvantage is that fish cannot feed anything except plankton that flows through the net, therefore fry may require some supplementary feed to grow faster, especially if the water is highly turbid for suspended clay during the rainy season, which limits the possibility to have good phytoplankton growth. A very important aspect of cage management is the need to change the net for cleaning every 10-15 days when it starts to get clogged by dirt. Dirt will in fact impede water to pass through the cage thus limiting the possibility to bring oxygenate water inside and to remove soluble wastes more efficiently. Lack of such maintenance would result in high fry mortality.

Fig. 26 Cage/pen positioned at the inlet of the paddy or in the irrigation canal

Fig. 27 A small hapa for nursing fry

| **Compartmentalized rice-fish in fish cages** | |
|---|---|
| **Advantages** | **Disadvantages** |
| • very easy setup<br>• does not require much earthwork<br>• highest protection of fry/fingerlings<br>• aquaculture can be done for nursery-only productions<br>• normal management as rice-only crop<br>• compatible with SRI management (see following chapter) | • fish require adequate cage volumes<br>• supplementary feed needed<br>• need to secure good water exchange<br>• need the hapa to be regularly cleaned<br>• if positioned in outer canal there may be risks of toxic contamination with other farmers' chemicals pouring into the canal<br>• risk of poaching |

A complete decoupled system can be a pond serving the rice field. This solution see the pond as a water reservoir of rain water collected during the rainy season. This solution is particularly good in places with long droughts or where the water streams get salinized during the dry season, thus making impossible to crop plants with adequate yields. The availability of freshwater during the dry season opens the possibility to have two rice crops (or rice and gram/beans) a year in areas where agriculture could be done only during the monsoon season.

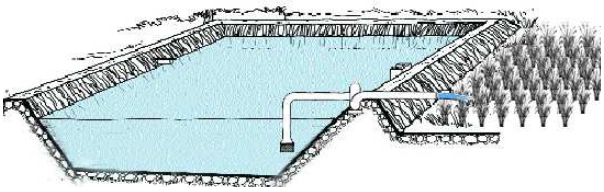


Fig. 28 Pond serving rice through a pump

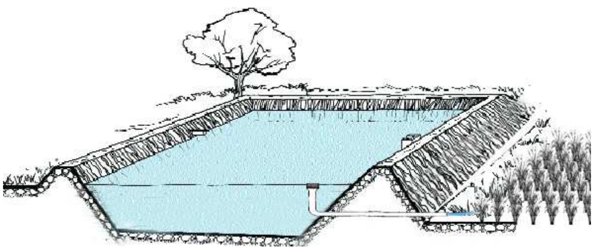


Fig. 29 Pond above rice level serving water through a pipe

| **Decoupled rice-fish in ponds**<br>**Advantages** | **Disadvantages** |
|---|---|
| • traditional fish management in pond<br>• possibility to intensify fish production as water is used to fertilize crops<br>• Traditional rice management, does not need to care about pest treatments harm to fish<br>• Freshwater storage to extend to two seasons a year the production of plants<br>• Freshwater also for household uses<br>• Compatible with SRI management (see following chapter) | • Required digging work<br>• Not beneficial effect from pest or diseases control by fish<br>• Mainly important for dry seasons<br>• Fish may require supplementary feed |

### *3.1.3 Polyculture*

Polyculture implies different solutions involving plants, livestock, and aquatic plants. A simple plant polyculture makes use of wider dikes for terrestrial plant that can surround rice-fish fields. Choices are numerous, from banana trees, cassava, beans, maize, lady finger, etc. The size of the dikes and rice fields can be adjusted to farmer's needs (Fig. 30).

The presence of crops and vegetation on the dykes could also make some shadow on the trenches that surround the rice field, this helps to reduce the water temperatures.

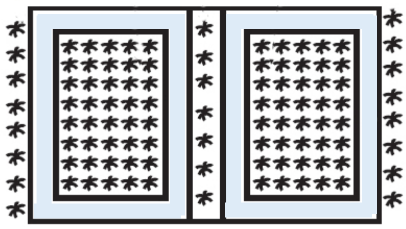


Fig. 29 Layout of fish, rice, plants

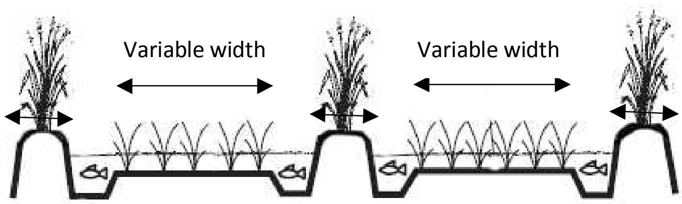



Fig. 30 Lateral view of fish, rice, plants. The width of the rice field and dikes can be variable

| Polyculture with plants | |
|---|---|
| **Advantages** | **Disadvantages** |
| • Add more production to the paddy area<br>• Differentiate the incomes<br>• Create micro environment favourable to fish (more shadow on water) | • Interactions between plants may be negative for the presence of pests |

One common interaction of rice and fish would see the addition of ducks or azolla or the combination of duck, fish, azolla and rice altogether. Ducks are very advantageous to get rid of pests in the fields. As described in the following chapters optimal pest management would consists of flood and dry cycles in the rice field to get rid respectively of terrestrial and aquatic pests. When the rice field is dry ducks can help controlling pests by walking in the field. In addition the swimming activities of the birds help the bottom to be re-suspended, which helps to avoid risks of methane production.

Azolla is an aquatic plants consumed by fish. It grows spontaneously and provides not only nutrients to fish but also nitrogen to rice plants. Azolla is in fact capable to fix nitrogen from the air.

Fig. 31 Ducks, fish and rice[1]

Fig. 32 Ducks, fish, rice and azolla[2]

Fig. 33 Azolla[3]

Livestock integration can be also supported by larger animals that provide nutrients with their wastes. Urine is an excellent fertilizer that can give large amounts of nitrogen, phosphorus and potassium without organic matter. As written before addition of manure in flooded conditions would reduce the oxygen to the water, thus creating anaerobic conditions that would harm the fish, and favour the production of methane in the water. Animal shelters can be suspended on the paddy fields. Ideally faeces should be collected in a pit and mixed with other by-products such as trashed straw or hulls and distributed during the dry season on the soil, while urine could be directly added to the water. A cow produces on average 13 litres a day of urine, equivalent to 210 g of nitrogen a day (NZ Herald, 2018).

Fig. 34 pig sty suspended on a paddy

Fig.35 Side view of a shelter and rice paddy

[1] Source: http://theazollafoundation.org/features/rice-duck-azolla-loach-cultivation/
[2] Ditto
[3] Source: https://en.wikipedia.org/wiki/Azolla

| Polyculture with animals<br>Advantages | Disadvantages |
|---|---|
| • Add more nutrients to the paddy (organic fertilization)<br>• Livestock already present as farmers' assets<br>• Reduction of costs for fertilization<br>• Control of pest (ducks)<br>• Resuspension of organic matter by ducks to avoid methane production<br>• Additional incomes/differentiation livelihood strategies | • Additional labour tasks for livestock waste management required if willing to comply with climate smart management<br>• Fodder for animals needed<br>• More complex management and skills required to manage different animals and crops |

### *3.1.4 Rotational culture*

It can happen that rice crops can be followed by a fish-only crop after the harvest of the plants.

This happens for example if fish need to grow over a longer period than the rice. The rice field is drained up while fish are kept in a deep trench or pond at one edge of the paddy. After the rice is harvested the fish can move freely again in the paddy that has been flooded again. The process of flooding is beneficial as it drown the insects and larvae that possibly hide into the crop residues.

The type of succession can encompass either larger fish that require 6 months to reach market size or more likely advanced nursery with fish juveniles growing under a high turnover of 30-45 days and then sold to fish farmers. In this case rice-fish farmers can have 2-3 crops with juvenile that can be stocked at ten time higher densities than grow-out fish and can bring quick cash to households. The fish-only cycle is normally done as a break period between two rice crops, but this choice depends on water availability, which should be guaranteed all year round.

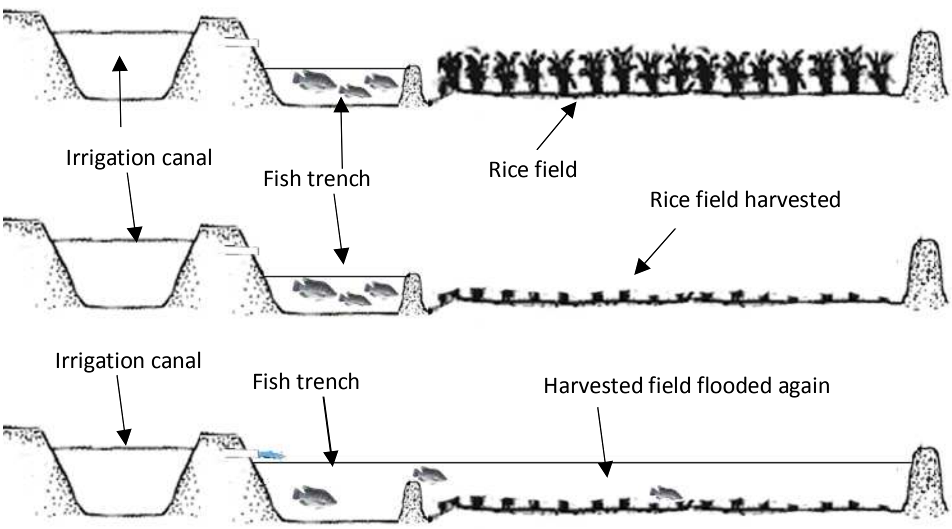



Fig. 36 Rice and fish successions

Another type of rotation could also consider other crops such as rice-fish during the rainy season and gram/beans during the dry season.

In some other cases the succession with rice follows the fish/prawn-only crop during the rainy season (Fig. 37). The transplant of the seedlings occurs during the dry season when the water level in the pond gets lower. Rice plants take advantage of the nutrient-rich sediments at the bottom of the pond. The bottom dries up towards the end of the dry season helping the organic-rich soil to be mineralized and sterilized by the sun for the successive fish/prawn-only culture.

Fig. 37 Rice crop in a prawn pond. An area of the field is kept deeper and open for the fish

## 3.2 Fish area layouts

Traditional rice-fish systems with both species concurrent at the same place and the same time should undergo a series of land modifications to host the fish.

### *3.2.1 Dike layout*

The presence of fish makes it necessary to raise the dikes for a sufficient height. Considering the need to increase the level of the water from 1 to at least 6-8 inches the main work consists to raise the whole structure up to 16-20 inches from the paddy bottom. This would guarantee at least 10-12 inches of margin to avoid fish from jumping out, or to avoid any possible escapee should a flooding occur during the rainy season. For such increase of water there is the need to build dikes large enough to withstand the bigger force carried out by the higher level of the water.

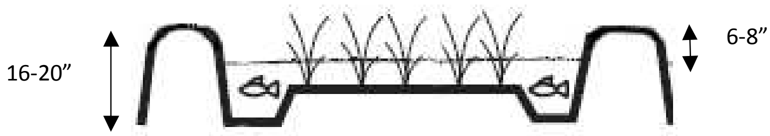



Fig. 38 Dyke height

### *3.2.2 Paddy inlet/outlet*

Paddies are normally not supplied of any breach in the dikes to drain the excess of water out, as the structure is fairly simple and tiny due to the low level of water that needs to be contained. In traditional paddies it is in fact sufficient to hoe the dike for a few feet to let the water out.

The presence of the fish requires a more active water management to level up or down the paddy, in this case rice-fish paddies with larger and taller embankments require a reliable gate to regulate the water. Designs can vary from very basic sluice gates, PVC pipes, hollow bamboo etc. Given the possibility of escapees when opening the gate during the exchange of water there is the need to provide a screen. The choice depends on the local materials available and the size of the fish. Smaller fish may better require a screen made with hapa net, while bigger fish can be contained with simple bamboo stakes.

Fig. 39 Water inlet by breaking a dyke[4]

Fig. 40 Water inlet with a PVC pipe and screen

### *3.2.3 Fish shelters*

The paddy should have a dedicated area with a deeper bottom to host the fish when:

- the young fish are nursed before the paddy is transplanted and flooded
- when the water in the rice area is progressively dried up for weeding or harvest
- when the fish need a refuge between one crop and the successive one
- to give fish relief in deeper water against the heat

The refuges have variable sizes and shapes, in many cases an impoundment is associated with a trench/s to favour mobility of the fish to/from the recovery area.

There are few rules that may need to be considered:

- The area should be big enough to accommodate fish during the drying period of the rice field without any risk of oxygen depletion for the aquatic animals
- The fish area should be optimized to maximize the paddy area (not too big, not too small)
- The depth should be adequate to guarantee cooler water at the bottom during the summer
- Should be reachable for inspections

In the case of trenches their width is 1-2 feet with depths of 1-2 feet below the cultivation level, but deeper/wider could apply. Their disposition can be at one side of the paddy (Fig. 10), or along the perimeter of the paddy (Fig. 11) or cross it to create different corridors that separate the rice field in sectors (Figs. 12, 13).

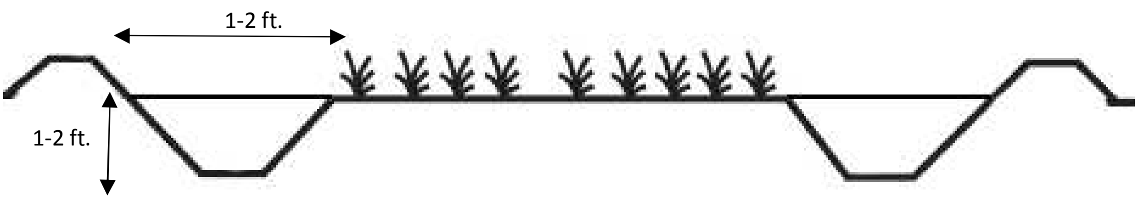
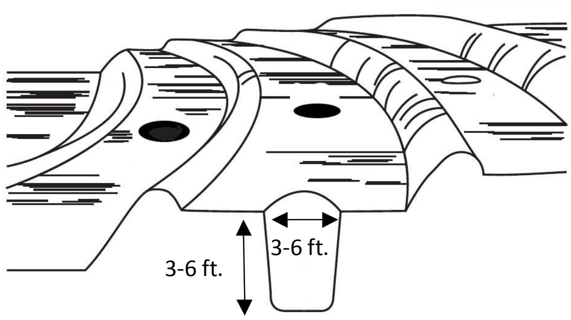



Fig. 41 Standard height and width of trenches in rice paddy (deeper are possible)

Smaller variants exist and consist in pits 3-6 ft. wide and 3-6 ft. deep, dug every 1,000 $ft^2$ of production area. The dimension of the pits can be also calculated to be within 1-5% of the whole paddy area. This type of system is pretty simple and can be adapted to many layouts, also including the terraced mountain paddies where the excavation of trenches may be not favourable for the particularly narrow size of the land.

[4] Source: uaex.edu University of Arkansas System



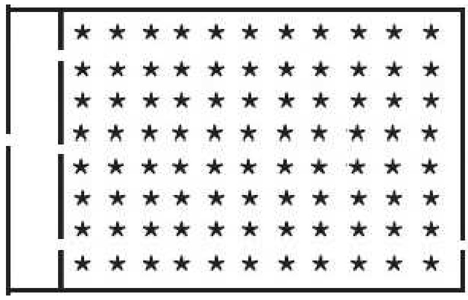



Fig. 42 Pit depth and width. One pit every 1,000 $ft^2$

Fig. 43 Pond area in a paddy. At least 5% of total surface (2,000 $ft^2$ per acre), 3-5 ft. deep

Larger variants are made as ponds that can be separable form paddies by means of dikes and gates. Inlet water from irrigation canals or rivers directly supply the fish ponds with water that is screened to prevent intrusion of unwanted animals or to prevent any escapees. The irrigation of the rice occurs with the pond water, which results enriched of some nutrients. The area dedicated to the fish pond can be at least 5% of the total paddy area (at least 2,000 $ft^2$ per acre) with depth of 3-5 ft. Optional trenches can be excavated within the rice area to facilitate the movement of the fish to/from the pond (Fig. 24). The advantage of such solution is that a separation can be established between fish and rice, thus allowing freedom in the agronomic management of the paddy and longer grow-out periods for fish that can be farmed across two paddy seasons. Fish find refuge in the pond only when the paddy is dried up for harvest, in this case biggest fish are also harvested leaving the juveniles to restock and grow during the successive cycle.

As mentioned before other alternatives already used in Myanmar consist in growing rice in ponds towards the end of the dry season. One part of the pond is dug to leave a refuge to fish when the water level decreases. Rice takes advantage of the nutrient-rich bottom of the ponds, which is full of organic matter from fish wastes. The progressive drying up of the pond eventually exposes the soil to the air, favouring the necessary mineralization and sterilization the soil for the successive fish batch.

The use of a net cage or pen to contain fish can be another solution for rice paddies. Such enclosures can be positioned in the lowest area of the paddy, following flooding events or when the water level is sufficiently high (1-2 feet) to stock juvenile fish that are nourished by the phytoplankton or supplemented feed.

## 3.3 Polyculture

In rice-fish systems it is common to see larger integrations of plants that go beyond the rice-only layout. The use of the lateral embankments of the paddies would in fact create areas for terrestrial crops, while the water spaces between the hills can accommodate aquatic macrophytes.

In China the rice-fish farming has been integrated with azolla. This type of aquatic plant not only provide food to the fish that swim underneath, but also support rice growth for its well-known capacity to fix nitrogen from the air into the water. The advantages appear evident as fish can yield 70% more when azolla is present in the culture.

Other types of polyculture include rice-fish-livestock and in particular ducks that can help to bioturbate the soil of the paddy but also biocontrol the snails that can affect the rice plants. Ducks can enter the rice field approximately 4 weeks after transplant. Ducks can control golden snail (*Pomacea* spp.) infestations even in small numbers (10 ducks/acre) and can be hold in small refuge ponds that can be shared with fish when necessary.

Fig. 44 Biocontrol and bioturbation by ducks

Fig. 45 Biocontrol and bioturbation by fish[5]

# 4. Main rice and fish species

## 4.1 Rice species

Modern high-yielding varieties are slightly less adapted to areas of deep flooding or to the depth required for fish culture. However the depth is less than a concern as many layouts can be used.

However,what may appear more limiting is the duration of the rice crops with precocious varieties, as the shorter time required for harvesting rice, in some cases below 100 days, may not be enough to the requirements of the fish to grow up to market size. Stocking bigger juveniles may not be sufficient, as bigger size fish may cause disturbances on the small plantlets (eating, pulling). In alternative smaller fingerlings could be stocked, but extra time in refuges is then required to let fish reach their target size, unless there is demand for smaller fish, such as Indonesia and the Philippines.

Rice culture could instead be attractive for particular productions of rice that require longer seasons (e.g. jasmine rice), in this case the time match between the rice and fish could also gain additional opportunities from organic or environmental-friendly certifications.

However, the choice of rice should more likely be done on the resistance of plants against specific diseases or pests. The selection should follow the disease monitoring by the dedicated ministries/departments in order efficiently plan supplies of certified and disease resistant varieties.

## 4.2 Fish species

The fish species to be chosen in paddies should meet the following characteristics:

- High tolerance to grow in shallow water
- High tolerance to high turbidity
- High tolerance to high temperatures
- High tolerance to high excursion between night and day
- High tolerance to low oxygen conditions, often occurring on hot days
- Good resistance to diseases
- High growth rate and ability to quickly reach market sizes
- Good tolerance to chemicals accidentally occurring in the paddy
- Must not escape from the enclosed field

Despite the apparent difficulties to match all these characteristics it seems that more than 35 species are already farmed in rice-fish systems and seven crustaceans (from four families) with no major

[5] Source: http://en.chinaculture.org/chineseway/2012-11/15/content_445962.htm

problems (Halwart and Gupta, 2004). Of course the type of management and the physical characteristics of the refuges can play a fundamental role in avoiding stress to fish.

What eventually determines the choice is the availability of juveniles by a local supplier/hatchery, since the species produced locally are obviously the most adapted for that climate. Apart the availability of hatcheries at local level it is also important to have the possibility to get the fish in the desired period, which may not be always granted.

Two groups of fish are mainstream: carps and tilapias. Carps are indeed widely documented and have a long farming tradition in China. The fish belonging to these two groups are either used in monoculture or polyculture. Nevertheless the choice can also be driven by the feeding habits of the fish, since a good balance between different feeding characteristics could improve the efficiency of the rice-fish ecosystem and help to control the organic matter settling at the bottom or the weeds in a more sustainable way.

Tab. 01 Fish and feed habits of common species in South East Asia

| Fish species | Scientific name | Feed habits |
|---|---|---|
| Common carp | *Cyprinus carpio* | Herbivorous/omnivorous, juveniles feed on zooplankton, phytoplankton. Adults feed on macro-benthos |
| Catla | *Catla catla* | Algae and dead plants |
| Rohu | *Labeo rohita* | Dead plant material |
| Mrigal | *Cirrhina mrigala* | Dead material on pond bottom |
| Grass carp | *Ctenopharyngodon idella* | Aquatic Weeds |
| Bighead carp | *Asistichthys noblis* | Zooplankton, tiny animals |
| Silver carp | *Hypophthalmichthys molitrix* | Phytoplankton and detritus |
| Black carp | *Mylopharyngodon piceus* | Molluscs |
| Mud carp | *Cirrhina molitorella* | Dead material on pond bottom |
| Silver barb | *Barbodes gonionotus* | Planktivorous |
| Tilapia | *Oreochromis sp.* | Omnivorous |
| Perch | *Anabas anabas* | Tiny animals, but also algae |
| Catfish | *Clarias sp* | Fishes, invertebrates, insects and zooplankton |
| Snakehead | *Channa sp.* | Zooplankton, tiny animals, insects |
| Mullet | *Mugil sp.* | Zooplankton, insect, then benthic detritivores |
| Barramundi | *Lates calcarifer* | Fish, aquatic insects and small crustaceans |

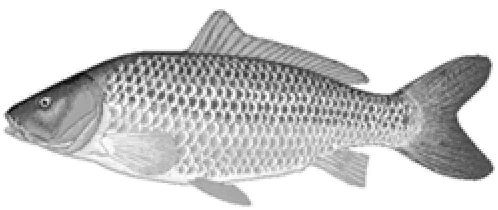


Fig. 46 Common carp

Fig . 47 Catla

Fig . 48 Rohu

Fig. 49 Mrigal

Fig. 50 Grass carp

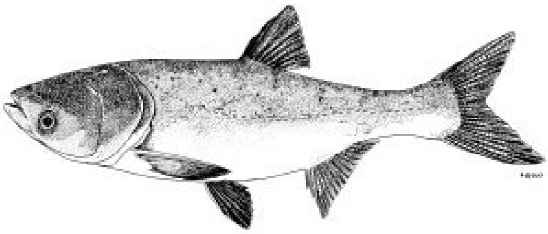


Fig. 51 Bighead carp

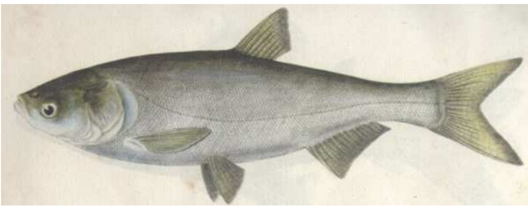


Fig. 52 Silver carp

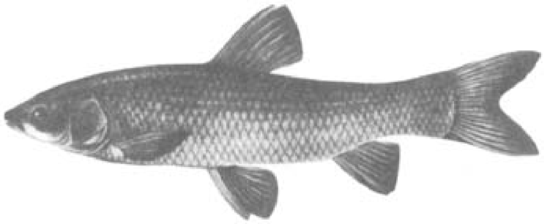


Fig. 53 Black carp

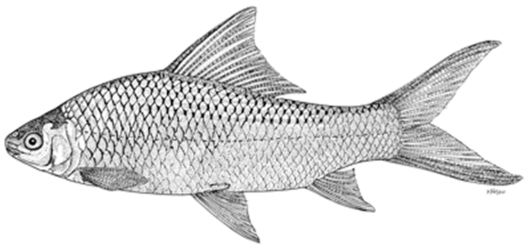


Fig. 54 Mud carp

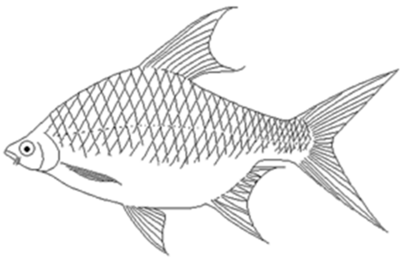


Fig. 55 Silver barb

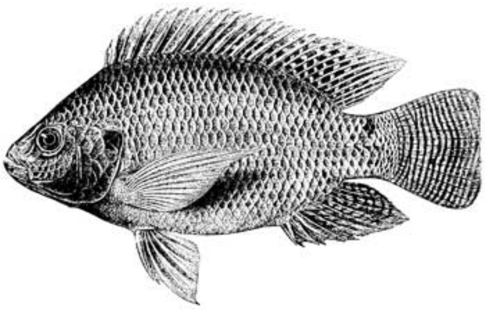


Fig. 56 Tilapia

Fig. 57 Perch

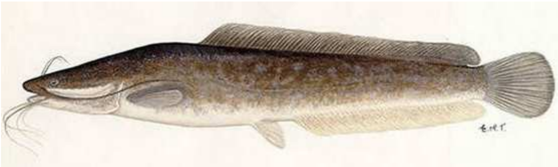


Fig. 58 Catfish

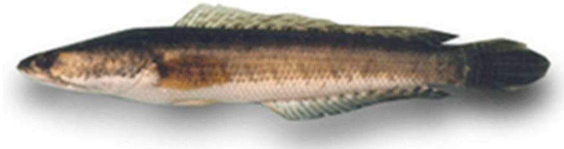


Fig. 59 Snakehead

Fig. 60 Mullet

Fig. 61 Barramundi

## 5. Agronomic and Aquaculture Management

Rice and fish systems imply the adaptation of the farming practices to reduce negative effects on fish. Such polyculture, especially if fish and rice cohabitate requires the perfect timing of the operations. Being too precocious with young seedling puts the plants at risk of being damaged by young herbivorous or omnivorous fishes; being too late with fish or stocking too young fish the probability of having high losses is likely to be high due to the presence of established predators.

The choice of the management is also adjusted by the production objectives. Rice is in general only cropped for 100-120 days while fish prefer longer season. This implies the need to keep fish over a longer period or across two paddy cycles in order to reach market sizes. Synchronous harvest of fish with rice is possible, but captures will only bring to smaller size animals of approximately 100-200 g.

The aquaculture management can also change depending on the locations and technologies available locally. At the very beginning rice-fish culture was mainly run as a trap and hold system where fish used to grow on primary productivity or on very few inputs (manure to crops, small quantities of fertilizers, basic feeds). Currently fry are obtained by hatcheries and this opens up a second market for nursing juvenile fish in very short cycles of 30-40 days, which can be repeated up to 3-4 times during the rice cycle. In this case fingerlings are obtained and sold to larger commercial fish farmers who seek to have bigger juveniles to shorten their grow-out period.

As specified earlier, the different optimal growth environments of the fish and the rice, as well as the need for specific pest control in plants can be favoured by the possibility to disjoin the two in compartments that can be connected when required or when the conditions are favourable. In this case, any rice irrigation needs is from water coming from the fish area, which can benefit from the slight fertilization effect of fish wastes, but not from the direct interaction of fish present in the paddy to control weeds and pests.

The rice-fish management could be done also in succession when a rice crop is followed by a fish crop colonizing the paddy after harvest (Fig. 36) by raising the dikes before the successive rice crop. The presence of the fish in the harvested paddy depends on the local environmental conditions (hot/cold climate) and water availability.

## 5.1 Preparation of the dikes and refuge

For rice-fish culture the dikes should be more robust than the rice-only system. The dikes are commonly at a height of 2ft, this to leave at least 1ft of elevation to avoid fish jumping out the water. The slope of the dikes should be 30-45°

The digging work of the refuge and/or trenches should be strategically designed to let the fish move towards it when the water drains. Also the bottom of the refuges may have a little slope to favour the complete removal of the water. As mentioned before the fish refuge should cover 5-10% of the whole paddy field and have a depth of 1-2 ft below the rice level, to guarantee at least 2 ft of water during the culturing. Deeper solutions are however acceptable to shelter the fish in cooler water at the bottom. The design of the trenches should favour water circulation and should allow the fish to move to them when water drains. Nevertheless refugee should be more likely positioned at the paddy inlet to favour of some water exchange. If sumps or larger impoundments are made, trenches should be dug to bring the fish to those recovery areas. An additional refuge could be also positioned at the outlet thus making a pair with the inlet. An overflow could be also made to avoid accidental flooding and thus losses of fish.

## 5.2 Preparation of the paddy soil

Wet the rice field with 1" of water for about 3−7 days until the soil is soft enough to be ploughed by the farmer equipment. The soil should be soft enough to be ploughed 4-8" deep, but also strong enough to give traction to the tiller or tractor. This operation can be done soon after harvest, also to get rid of pests and pathogens by putting crop residues under soil and then flood the field for a few days. Alternatively earthwork can be done at the beginning of the following crop season, depending on soil moisture and water availability. After plough keep the area flooded to soften the clods and to decompose the crop residues. The successive puddling and harrowing should be done a couple of weeks after the ploughing. One or two harrow passes may be necessary. Before transplanting or the sowing seeds a levelling off of the field may be necessary.

Fig. 62 Plough soil and crop residues

Fig. 63 Puddling the field

Fig. 64 Harrow passes

## 5.3 Fertilization

A good balance of nutrients is important. Too low nitrogen impacts on the tillering and size of the plants and bring them to shift their colour from green to yellow-green (chlorosis). On the contrary excessive nitrogen brings the plants to elongate excessively (spinning), which weakens the stems' resistance against wind or pathogens, thus resulting in the plants collapsing to the ground or to get diseases much more easily.

On the other hand phosphorus helps the tillering of the plants in synergy with the nitrogen and sustains the development of a good root systems. Phosphorus might be limiting in soils that are rich in aluminium or iron, however the water submersion of the soil help to free it back. In general water increases in consistent ways the availability of the phosphorus.

Potassium helps the uptake of nitrogen and phosphorus, particularly during the tillering phase, it favours bigger sizes of the grains, avoids the stretching of the plants that could bring to its collapse onto the ground, and gives an augmented resistance against diseases.

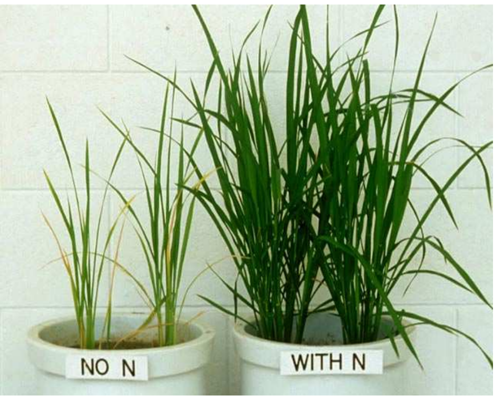



Fig. 62 Nitrogen deficiency, yellow leaves stunted growth limited tillering[6]

Fig.63 Nitrogen excess causes plants to be too green too long, tissues too soft, ideal for pest & diseases[7]

It is important to remind that fertilizers must be released slowly and not run off the crops. Flooded rice uptakes nitrogen mainly as ammonia, while in dry-soil conditions the nitrate form is favoured.

The quantity of nitrogen fertilization between rice-fish and rice-only systems does not vary during the initial stage of the crops, this due to the limited fertilizing support that small fish can give. However, the fertilization management between the two systems differs later in the season when fish start to actively contribute to mobilize nutrients to the plants (depending on the fish densities and if supplemental feed is given). Although slight fertilization losses are accounted to fertilize the water for plankton production to support the growth of juvenile fish, the presence of fish in the paddies is a net improver of the fertility and fertilization use efficiency. Fish in fact remobilize the nutrients entrapped into the weeds that are in part digested to promote body mass growth and in part excreted as faeces and urine to the benefit of rice yields.

The incorporation of nitrogen fertilizer into the soil during land preparation is more effective than broadcasting it on the surface. Fertilizers entrapped into the soil have slower release, which avoids to be run off or got lost into the atmosphere due to denitrification. Slower nitrogen releases also help fish to avoid fish poisoning if ammonia-rich fertilizers are used. Slow release forms of nitrogen are sulphur coated urea and urea super granules, or slow-release compound fertilizers (NPK). Successive top dressing fertilizations to boost productivity are done at surface level instead. In these cases fish need to be confined into the refuges by reducing the level of the water to avoid any risk of ammonia toxicity and to expose the fertilizer directly to the plants and soil.

The nutrient requirements are slow when the plantlets are small but they progressively increase up to the flowering stage. During the maturation phase the intake of nitrogen is reduced to 70%.

In traditional rice-only systems the nitrogen supply as fertilizer is in the order of 30-60 kg/acre of which 60-70% is incorporated into the soil at the beginning. The main types of nitrogen sources are urea, which has slower release, and ammonium sulphate. The successive top dress fertilization should occur

[6] Source: http://www.knowledgebank.irri.org/training/fact-sheets/nutrient-management/deficiencies-and-toxicities-fact-sheet
[7] Source: ditto

at the end of the tillering and before the appearance of the buds. The supply can be in the form of urea, combined with potassium chloride distributed on a dried soil or very still water.

One advantages of rice-fish systems is that the successive nitrogen fertilizations could be reduced and substituted with the supply of pelleted feed instead. Fish would grow much faster and bigger and at the same time would fertilize the paddy with their excrements.


Fig. 64 Phosphorus deficiency causes stunted plants, reduced tillering, older leaves are narrow, short, very erect, stems are thin and spindly and plant development is retarded[8]

Phosphorus quantities should be in the order of 20-30 kg/acre of $P_2O_5$ (equivalent to 45-65 kg/acre of TSP) to be included into the soil before the seeding in rice-only systems. However in rice-fish systems the fertilizer could be broadcasted on the surface also to favour the growth of the phytoplankton.

Phosphorus intake is much slower of nitrogen and it is maximum towards the flowering, but drops to zero during maturation.

Considering the run off of the water into the paddies the supplement of 15-28 kg/acre of potassium is suggested. The amount of potassium supplied may vary also considering that the practice of burning straws in the field would return some nutrients into the soil, but would progressively reduce the amount of important organic matter into the soil. Potassium absorption is maximum during the tillering (45 days from sowing). At flowering the plant has already taken 75% of all its needs.

Sulphur has similar uptake patterns of nitrogen, but calcium uptake is overall slow. Liming is also commonly practiced during the preparation of the rice field at the rate of 180 kg/acre

Organic fertilization with inclusion of manure is an important amendment to keep the organic matter of the soil and maintain fertility. In particular manure has low levels of nitrogen compared to synthetic fertilizers that makes it an ideal element to slowly release the nutrients and avoid their losses. To achieve best results organic fertilizers should be incorporated into the soil several weeks before transplant to let the organic matter to mineralize.

Inclusion of straw residues into the soil during the ploughing is also another good addition, although it may result a little bit more complicated if the stems are not threshed. On this matter in Indonesia the harvested paddy with its residues is left flooded to let the organic wastes decay for a few days

[8] Source: ditto

before restocking the paddy with new water and let the fish roaming in the field (Palawija ikan system). Softened plant residues would eventually be the substrate for microorganisms and planktonic organisms that will be successively eaten by benthic or planktonic fish, which will re-establish the cycle of the nutrients back to the plants.

Fig. 65 Potassium deficiency. Dark green plants with yellowish brown leaf margins and tips. Old leaves become brown[10]


Fig. 66 sulphur deficiency yellowing or pale green colour of the whole plan[9]

## 5.4 Rice management

In general the rice season starts with the rain, when the field gets wet to support seeds germination. Rice can be sowed directly or by transplanting young seedling from the nurseries.

There could be more than one rice crop a year, but this depends on the water availability, climatic condition of the area, fertility of the soil. In some regions rice could be followed by other crop that are less water demanding or supposed to improve soil fertility (beans/gram).

Genetic improvement has now brought to high-yielding varieties that have less duration (105-125 days), and better resistance against stress. This goes in combination with better agronomic techniques, fertilization strategies, integrated pest and disease management and water optimization. Obviously the choice of the rice beyond being driven by its marketability, should take into account the length of the crop, since a longer seasons would obtain bigger market-size fish.

Being rice the main crop fish should adapt to the planned agronomic tasks and to the water management, which will be eventually reduced to bring rice to the harvest.

Fingerlings could be stocked in the paddy four weeks after the sowing or one week after the transplant of the seedlings. In general the seedling that are transplanted are 30 days old and are 6-8 inches tall. Plantlets are transplanted with patterns of 8x8 inches, 9x9 inches or 10x10 inches. During the transplant the paddy is left dry or with no more than 2 inches of water. Higher quantity of water will be added few days after transplanting.

The important rule is that rice plantlets should be sufficiently strong and big to avoid the attack from fingerlings, but this also depends on the size of the fish and the type of aquatic species farmed. Management of bottom feeder or carnivorous fish is in fact much easier than omnivorous species like tilapia or other herbivorous fish that are mainly targeting tender plants.

Carp would in fact pull out the small unrooted and weak plantlets if they are not kept separated by the rice area by means of low water level or by raising a physical barrier around the refuge to avoid

[9] Source: ditto
[10] Source: ditto

the animals to trespass. Once the plants are big enough the whole rice area is flooded up to 4-8", leaving the trenches with at least 15-25 inches of water to host even the least tolerant animals.

Fish are then reared for the whole crop cycle of the rice (100 days or more depending on the rice variety). Depending on the farm layout, climate and water availability fish can be either harvested contemporary with rice or left growing in their impoundment thereafter.

In most of the cases rice paddies are cultivated only once a year and then left fallow due to water scarcity. However the dry period helps to mineralize the soil and to control snails and pests that would thrive in the presence of water. However, where freshwater is available for longer periods of time farmers can grow a second rice-fish crop or use their lands as a shallow pond for fish or fish and ducks.

In rice-fish culture it is always important to avoid any type of chemical input for plant protection or heavy fertilization. In the case of weeds the priority should be put on manual/mechanical rather than chemical removal with weedicides.

## 5.5 Fish management

### *5.5.1 Fish choice*

Omnivorous species (common carp, crucian carp, and tilapia) usually account for 60–80% of the total stocking, while herbivorous species (grass carp and blunt snout bream) account for 20–40% of the total stocking. A good balance is recommended as a way to optimize the resources that are available in the pond. The control of certain pests, like snails may suggest the choice of black carp or other predatory fish that can reduce the losses from the plants.

### *5.5.2 Land preparation*

The rice field is prepared by cleaning it from weeds and vegetation, ploughing and incorporating manure/cultural residues and fertilizers into the soil, preparing or repairing the dikes, trenches, sumps, water inlet, and outlet. The water inlet and outlet are provided with suitable screens and nets so that trash fish would not enter the field and the fish stocked would not escape.

### *5.5.3 Stocking and nursing*

The number and size of fish stocked would depend on the type of culture and species and local conditions. Small fry farmed and sold as fingerlings after a period of 1 month can be stocked at much higher densities. Fingerling stocked for table-size fish can be in higher number than market-size fish due to their smaller dimensions at harvest.

Fig. 67 Stock fry in nets to avoid predation. Acclimatize the fish by keeping bags on water before release the fish in the cage

Fig. 68 give supplementary feed to help the fish growth

In Taiwan and Africa the density of 3-5 cm tilapia is 1,200 – 3,200 juveniles per acre, but densities of fingerlings vary from 400 to 4,000 per acre. In West Java, common carp of size 3-5 cm or 5-8 cm are stocked at 2 000/acre without feeding while in North Sumatra common carp sized 30-50 g or 50-100 g are stocked at a rate 400-600/acre if no supplementary feed is supplied or 600-1200/acre if the fish get some food integration (Dela Cruz, 2001).

Tab.02 Stocking densities for rearing fish in rice fields

| Monoculture | Concurrent crop<br>Density num./acre | Alternate crop<br>Density num./acre |
|---|---|---|
| Nile tilapia | 1200-2000 | 4000 |
| common carp | 1200-1400 | |
| silver barb | 1200 | |
| **Polyculture** | | |
| Nile tilapia + common carp | 1200 + 800 | (2400-4000) + (1800-2000) |
| common carp + silver barb | 1850 in total | |
| c. carp + barb + tilapia | 3700 in total | |
| c. carp + goldfish + grass carp | (600-900) + (300-480) + (120-180) | |
| Nile tilapia + c. carp + grass carp | (6-10 cm: 2400-3600 or 3 cm: 4800-7200) + (120-240) + (60-120) | |
| **Fingerling production** | | |
| 1-3 cm c. carp (30 days) | | 28000-40000 |
| 3-5 cm c. carp (50 days) | | 4000-6000 |
| 5-8 cm c. carp (50 days) | | 2400–4000 |
| 5- 8 cm c. carp (50-90 days) | | 600-1200 |
| 8-11 cm c. carp (30 days) | | 400-800 |

(Source: Gupta et al. 1998; Li and Pan 1992; Sevilleja 1992; Quyen et al. 1992; Costa-Pierce 1992).

The density of the fish obviously depends on the fertility and richness of the paddies, but if supplementary feed is supplied along the season nearly twice the number of fish can be stocked. However the stocking densities are always lower than those possible in a traditional pond where the volume of water is much larger and there are no restriction in the regime of water.

Fish could be already nursed in the sumps to take advantage of more growing days, particularly if they are of small dimensions. In this case it is important to avoid any predations by birds, snakes, frogs or insect larvae by keeping the juveniles in a hapa net that needs to be always clean to let the water pass through.

Fish fry or fingerlings eat the plankton growing in the paddy, but particularly during the initial stages of the crop they should be given supplemental feed at 4-5% of body weight (BW). Commonly used feeds include fine rice bran, wheat, soybean cake, and groundnut cake for both herbivorous and omnivorous species. Pellets can be also used but their size should match the fish gapes.

If the paddy is used as a nursery to produce fingerlings the fertilization of the pond becomes the most important task to succeed in increasing the natural food production. Feed is however necessary in case of higher stocking densities, or to reach the target size of the fish in a faster way given optimal environmental conditions.

### *5.5.4 Grow out*

After the transplantation of seedlings is over (with a little of water only on the bottom favouring rooting of the seedlings), water level is raised to 4 – 8", so that the fingerlings can swim in the field. Fish are normally feeding on the natural food of the paddy, however from time to time they should be given additional feed depending on local resources. Rice bran, rice and other agricultural products like wheat, maize, cassava, grass and oil cakes (groundnut, soybean meal, etc) can be used. Home-made options could be also employed by making fresh pellet with local ingredient mixed with by-products (ground offal, blood meal, insect larvae, etc.). Alternatively pellets could be given. The nutrient regime at this time can be 1-2% BW. With crop cycles of 3-4 months farmers should expect to have 80-120 kg/acre, but if feed is supplemented the volume at harvest can be up to 180-250 kg/acre.

# 6. Climate smart management practices

## 6.1 The System of Rice Intensification (SRI)

Rice production greatly affects climate change through emissions methane ($CH_4$) and nitrous oxide ($N_2O$) gases, which are 25 and 298 times more dangerous than carbon dioxide. Methane is produced from decomposing organic matter under water and no oxygen, while nitrous oxide it produced by the anaerobic decomposition of nitrogen fertilizers. Eventually fertilization, if not properly managed, brings to big losses of nutrients, since excessive nitrogen is just lost in the atmosphere and not taken by the plants. It is therefore necessary to adjust modern farming techniques by limiting the conditions that determine the loss of fertilizers and the production of dangerous gases for the climate.

Aquaculture can greatly help rice yields through bioturbation and control of benthos in flooded rice (rain fed). In concurrent rice-fish paddy, whose manure inclusion in the soil should occur well ahead the transplant to let the organic matter settle and mineralize, fish can actively control the organic wastes and plant residues by actively feeding on benthos and by re-suspending the organic matter settled at the bottom by swimming around the hills. Furthermore, the continuous releases of small amount of faeces ad urine guarantee good mixes of nutrients low in nitrogen that can fertilize rice plants with limited risks of $N_2O$ productions. In the overall footprint this support of nitrogen and nutrients by fish is overall essential, as it prevents the use of fuel-demanding fertilizers of synthetic origin and avoid the eutrophication of open waters by aquaculture wastewater.

Advances in rice farming are also in non-flooded rice culture methods, as they are apparently much more productive with less gas emissions: this opens up great opportunities for productions in the dry seasons (irrigated rice) across South East Asia or the rest of the world.

System of Rice Intensification (SRI) has been validated in more than 50 countries worldwide. In SRI soil is kept humid but not flooded to favour aerobic bacteria. Fertilization is through organic matter, which is a much slower nitrogen-releasing than chemical fertilizers. Lack of floods and minimum nitrogen supply combined to organic matter helps to consistently abate greenhouse gases.


Fig.70 SRI growth (source Abbas Hameed, 2018)

With SRI practices, roots grow larger and deeper and do not degenerate for lack of oxygen in the soil, as occurs when rice fields are kept continuously flooded. The main principles ruling SRI are:

- Early transplanting of seedlings (8 to 15 days old)
- Seedling singly transplanted, one plantlet for hill
- Wide spacing of 10 x 10 inches between the plants
- Keep the soil moist, not wet nor flooded though regulated intermittent irrigation
- irrigation is followed by dry periods of 3 to 6 days
- Manual or mechanical weeding, no use of herbicides
- Use of organic manure to boost soil fertility
- Limited or no use of chemical fertilizers
- Stimulation of aerobic micro-organisms of the soil that are in free air.
- Once the plants flower, the field is kept under a thin layer of water until 20 days before the harvest

Since the 1980s, numerous trials have shown that SRI outperform traditional flooded-rice production, while reducing the use of water, seed, fertilizer and pesticide. The system was found to improve grain yields above those obtained under flooded systems by 40% and in some cases even 200%. Rice grown using SRI consumes 25 to 47% less water and requires 10 to 20% less seeds.

Fig. 71 SRI on moist soil[11]

Fig. 72 Moist soil conditions[12]

**Key advantages:**

- Higher yields of more than 40%
- Soil health is improved and the plants' access to nutrients is enhanced as well as their physiological development
- Reduced greenhouse gases emissions
- Seedlings can be planted on zero-tilled permanent raised beds under mulch
- Increases of net incomes per hectare by almost US$200

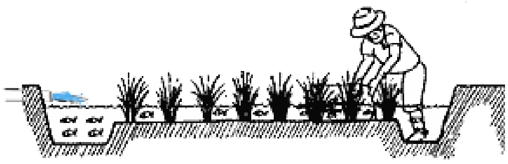
SRI can be included in climate friendly decoupled rice-fish systems with irrigation water coming from pond stocked with fish supplying nutrients and organic matter to the rice fields that are only managed in moist conditions (no flooded).

Obviously SRI in monsoon regions is likely to be done during dry season, while in rainy seasons paddy fields could be managed as rice-fish, but with less/no use of manure during flooded conditions, little but regular fertilization with slow-release fertilizers and concurrent fish culture for bioturbation.

---

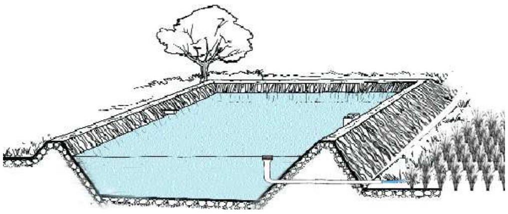
[11] Source http://sri.ciifad.cornell.edu/news/features/2014/featured0614.html

[12] Source: ditto



**Benefits of concurrent rice-fish**
- Bioturbation of bottom
- Fish cleaning benthos
- Pest control
- Fish/plant disease control (with probiotics)

Fig. 73 Concurrent culture in monsoon rice



**Benefits of fish pond serving SRI**
- Pond as reservoir of freshwater and nutrients in salinized/dry areas
- No pollution from intensive fish farming
- no risks of chemical contamination to fish from any treatments on rice

Fig. 74 Decoupled system with SRI in dry season

## 6.2 Smart fish irrigation of rice in salinized areas

Saltwater intrusion is annually seen in the coastal and estuarine areas. During prolonged periods of dryness saltwater invades water streams and rivers, going upstream for miles. Salinity depresses agricultural productions: each gram of salt in water above the limit of 1.5 g/L depresses yields by 24%. As a result in many areas lands are not cultivated during the dry season or are farmed with losses. Climate change is expected to worsen, with longer periods of droughts and raise of sea level.

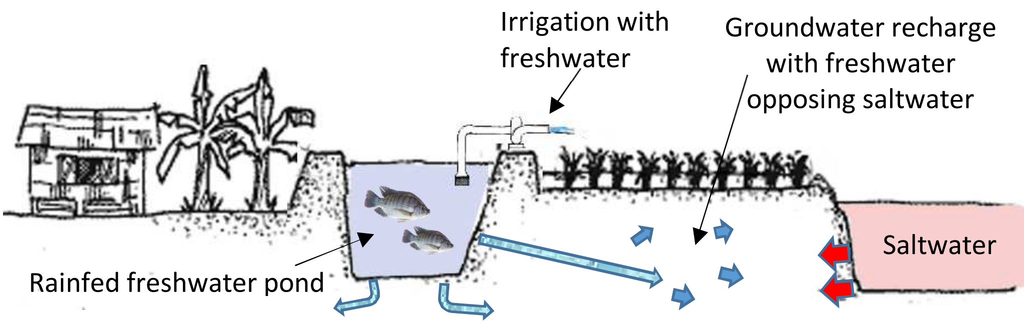



Fig. 75 benefits of storage and supply of freshwater

Aquaculture can give a great support against saltwater by substituting the irrigation from salinized canals/rivers during the dry season with water from rain-fed deep ponds or reservoirs stocked with fish. The abundance of rain in some areas of S.E. Asia allows for the full storage of rainwater in ponds, if these were built.

By using a limited part of agricultural land for water storages it is possible to double the land productivity with two crop seasons a year. The action of ponds is double:

1. Direct irrigation in dry season
2. Recharge of groundwater with freshwater

Benefits

- Two rice crops a year instead of one
- Increase water productivity with fish and plants using the same water
- No need to clear mangrove forests to produce more rice
- Fish wastes used for fertilization
- Water for household use

- Recharge of the aquifers with freshwater instead of saltwater
- Additional incomes from fish
- Improved livelihoods and nutrition
- Improved livelihoods prevent rural people emigrate elsewhere

## 7. Integrated pests and diseases management

Pest and disease management considers different strategies that can be summarized in four groups:

- **Mechanical management** is the most used. It considers weeding carried out through human extirpation, mechanical tillage, waste management, or grazing from the fish.
- **Chemical management** always recall synthetic products whose toxicity is well known by fish farmers. However there are substances produced by plants that are likely to prevent attacks, favour repulsion or provide antibiosis against pests or pathogens.
- **Cultural management** use agronomic management that would minimize the risks of pests of disease infestations: irrigation/flooding, resistant cultivars, plants' separation, and fertilization.
- **Biological management** makes use of organisms or microorganisms to control pests of pathogens through competition or predation.

Fish is a biological agent for its multiple roles in controlling pests or diseases in the water or by removing contaminated or rotting residues that could spread the infection or infestation into the plants. To be effective the biological control should be in close contact with the pathogen/pest. In general a biological agent controls specific pests or diseases, but it could never completely eradicate it, although it can keep the situation under control with insignificant damages. The use of chemicals is most of the time non-specific, this means that a chemical product kills without discerning between good and bad organisms. What results is indeed a control, but the success might be only temporary and could lead to much more difficult situations: a pest escaping a non-specific insecticide may not have any beneficial insects that could control it, which results in a much serious attack afterwards.

Nevertheless any treatment should always be chosen against a cost-benefit analysis to verify if the advantage gained is bigger than the drawbacks or production losses. Furthermore the choice of any treatment should be made based on:

- the least damage to fish
- risks of accumulation
- Persistence (the chemical remains active in the environment for long time).

When farming fish the use of chemicals must be restricted to a maximus, since any treatment would bring in consequences that are difficult to control or would increase the risks of death in fish.

## 8. Weed control

Fish are particularly good at controlling weeds in the rice field. The weeding is carried out by either herbivorous fish that graze on the plants, or by the bottom feeders that simply uprooting them in their search of food. Common carps provide an excellent weeding service together with Java barb (*Barbonymus gonionotus*) and Snakeskin gourami, which are only inferior to the herbivorous grass carp (*C. idellus*). Among tilapias the *O. mossambicus* is more favoured than *O. niloticus* that seems to prefer more microalgae. Additional work may be done by the farmers, such as the cleaning of the banks, whose grass can be given either to fish or grazing animals, or in doing the tipping of the rice leaves to reduce the incidence of the pests.

# 9. Pest control strategies for rice

## 9.1 Pest control with fish

Biological control of pests is mainstream in rice-fish systems with fish and beneficial insects actively protecting the rice crops. It has been observed that pests are more present in rice-only systems, due to a lower presence of antagonists.

Common carp *C. carpio* and grass carp *C. idellus* are effective in controlling leafhoppers and planthoppers. By removing the outer leaves of the rice plants they also get rid of the eggs of the pests. A more direct control is also done by actively eating the hoppers that can fall in the water. Fish also control stem borers. The fish apparently predate the stem borer larvae that get suspended with a thread on the leaves, when they start to move to other plants or hills.

Snail and crabs are invertebrates that infest crops. In traditional rice-only cultivation chemical baits are used but are not very effective. The use of fish, such as common carp is preferred as biocontrol agent because it is capable of daily consumption rates of up to 1 000 juvenile snails, as well as larger snails. A fish that specifically targets the snails is the black carp, adult fish are very effective in controlling adult snails. Alternatively a good control compatible with fish is also done by ducks that can roam in dry soil conditions and can also predate crablets.

The presence of fish also help to control the larvae of mosquitoes that could bring diseases such as malaria and dengue fever. Rice-fish can support programs of eradication in infested areas.

## 9.2 Cultural practices

### *9.2.1 Planting Methods*

Direct seeding on non-flooded soil is favourable to keep away pests that prefer the presence of water such as water weevil, rice caseworms and whorl maggots. Direct seeding also seems to be less affected by stem borer damages than transplanted crops.

On the contrary doing transplant in flooded paddies control all land based pests such as white grubs, root aphids, termites, mole cricket, ants. Growing rice in a seedbed can give some advantages due to the limited area needed that can be protected by physical barriers (tight insect nets) or even treated with organic/chemical insecticides long before being transplanted into field. Spraying at nursery stages avoids risks of any possible pests accidentally infesting the fields. Seedbeds also help to shorten the production cycle in the field, which lead to shorter risks of having attacks of pests or diseases:

- Bigger seedlings transplanted are less affected by caseworms and whorl maggots and can skip one generation of stem borers and brown planthoppers, thus reducing the eventual damages.
- The presence of disease transmitting pests would in fact have smaller impact since bigger plants will give less time to the vector-transmitted diseases to propagate and damage the crops.

Delayed transplants (45 days old seedlings) would reduce losses, although this could undermine the maximum productivity achievable from young seedling (21 day old) due to reduced tillering in rice. However this issue could be bypassed if 3-4 plants per hill are transplanted instead.

### *9.2.2 Planting Density*

The effect of plant density on pest is various. High planting densities would create a different climate inside the canopy (more humidity, less temperatures) and the physical contact of plants would ease the movements of no-flying insects. Dense planting increases populations of planthoppers, leafhoppers, leaffolders, gall midges, black bugs. Lower densities would create a physical barrier but would also promote weed growth and could be less productive than high densities paddies. Lower number of plants would also determine more serious attacks by pests as insects concentrate more in fewer plants.

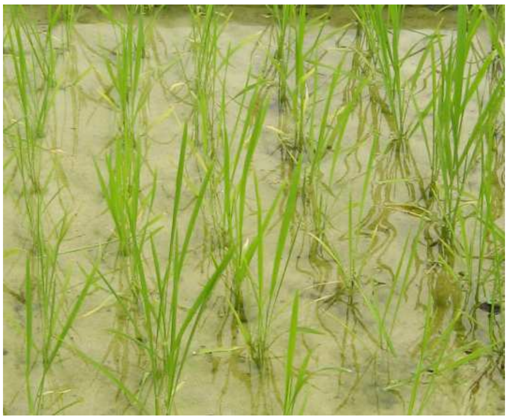


Fig. 76 correct spacing and age is important to reduce pest and diseases incidence

Fig. 77 control of weeds help to reduce the incidence of pests[13]

### *9.2.3 Crop companions*

The presence of azolla covering the water during the initial stages of the paddy would not only provide nitrogen to the rice but also reduce the incidence of whorl maggot. With water coverage predators could easily move to target the pests.

### *9.2.4 Water management*

Lack of water for 1 or 2 days in a drained field would suppress pests such as whorl maggots, root feeding midges, water weevils, and caseworms due to the effects of the absence of water on the respiration.

Flood and drain done for 5-7 days can reduce the incidence of semi-aquatic insects. Drained conditions would in fact impact insect like black bugs, hopperburn, planthoppers, armyworms, gall midge, hispa, and most stem borers. Polyculture with ducks would be also useful as the absence of fish during the drain periods could be compensated by the presence of ducks that would roam around the hills in search of prey. However frequency of action is of key importance due to the possible losses of nitrogen for alternate cycles of aerobic (dry)/anaerobic (flood) conditions.

The absence of water increases the uptake of calcium, which helps to compact the walls of the vegetable cells that will become more resistant against pathogens and pests. On the contrary lack of water could be a promoting factor of weeds, however these could be successively controlled by fish.

Flooded conditions are instead favourable to control land-based pests such as armyworms, grasshoppers, trips, ants, white grubs, mole crickets, root aphids, termites, root weevils, and seedling maggots.

### *9.2.5 Fertilization*

High rate of nitrogen stimulate intense vegetative growth of the plants. But if the growth is too fast the plant tissues will be juicier and softer and more attractive to pests, fungal and bacterial attacks. Pests would eventually find a better nutritional environment and thus will become bigger and more prolific. High rate of nitrogen will also negatively affect the tillering.

---

[13] Source: http://www.knowledgebank.irri.org/step-by-step-production/growth/weed-management/manual-and-mechanical-weeding

Fig. 78 Flooded conditions control land-based pests

Fig. 79 Dry soil controls semi-aquatic insects

To balance the important role played by nitrogen in supporting the crop growth and to avoid the risks of facilitated pest and disease attacks it is suggested to split its distribution in many times with reasonable quantities, and to use slow release forms (such as sulphur coated urea and urea super granules) or slow-release compound fertilizers (NPK). Inclusion in the soil of fertilizers during the tillage or puddling helps to maintain the nutrients over a longer period of time.

Phosphorus has an indirect effect to growth as it works together with nitrogen, therefore the supplement of this fertilizer should be considered in conjunction with the supply of nitrogen. However one positive effect phosphorus brings is the intense root growth, this would be eventually beneficial against the damage of weevil at root level.

Potassium is beneficial for rice crops as it slows down growth of the plants, induces tillering, hardens the cells' walls, which helps to make it harder to pathogens to attack. At pest level the low levels of sugars and amino acids determined by potassium depresses the growth of whorl maggot, green leafhopper, yellow stem borer, brown planthopper, thrips, and leaf folders. Potassium also stimulates the production of allochemicals that are repellent for insects and promotes the absorption of silica that hardens cell walls, which makes it harder for the stem borer larvae to feed on the plant tissues.

### *9.2.6 Crop rotation*

Crop rotation is a common agronomic practice that breaks the cycle of transmission of pests and diseases in the field. It works particularly well to control pests that have limited host choices, do no move much and have long life cycles. Crop rotation can efficiently control gall midge, stem borers, white grubs, termites, planthoppers, seed bugs, and armyworms, but to be effective it needs to be widely adopted and synchronized over a big area of hundreds or thousands of acres.

### *9.2.7 Crop Area*

Infestation of pests depends on the extension of the area and mobility of pests. Some migrate by flying, while other move. A crop that has a big in extension is more likely to get higher infestation that a smaller crop.

The separation of the target plants from the surrounding vegetation plays a big role to prevent pest transmission. However the possibility for pest to attack a rice field depends also on the surrounding vegetation.

A trench surrounding a rice field along all its perimeter makes it more difficult for pests to walk in due to the physical barrier of the water. Likewise buffer zones with no vegetation or repellent plants may prevent the migration of pests to the rice field. Buffer zones could be also effective against flying pests but this also depends on the local wind conditions and how far a pest can fly.

### *9.2.8 Rice successions*

The continuous succession of same cultures along the year has a favouring effect for the occurrence of the pests but also their natural enemies. A fallow period, as it happens in the rural areas in Myanmar, lowers pest incidence. But continuous crops increase exponentially the presence of whorl maggot, leaffolders, black bug, leafhoppers, planthoppers, thrips, and stem borers.

Insects that have advantages compared to the others are those that are monophagous and able to settle and reproduce in all the growth stages of the plants: brown planthopper, green leafhopper, yellow stem borer, and gall midge.

### *9.2.9 Rice varieties*

Early maturing varieties are particularly favoured to avoid high incidence of pests due to their short production cycles that do not allow pests to complete their reproduction cycles: stem borers, armyworms, gall midge, leaffolders, white grubs, leafhoppers and plant hoppers. This strategy is particularly effective for early maturing varieties cultivated after a fallow period. It is important to remember that early maturing cultivars are low yielding as their vegetative part is not large enough to support the energy needs of many rice grains, but their short cycles allow farmers to best adapt their planting times in order to avoid pests. However the small size of these plants makes the recovery more difficult should they be affected by pests.

### *9.2.10 Time management*

***Shifting the planting time*** can disadvantage the pests that miss in this way their optimum window consisting in weather conditions, temperatures, crop growth stage, or presence of natural enemies. However the shifting is highly specific to the local conditions. Anticipation in planting may have an effect on gall midge, thrips, grasshoppers, leaf beetles, stem borers, root weevils, leafhoppers, planthoppers, seed bugs, and whorl maggots in some areas. Delay in planting can instead adversely affect seedling maggots, leaffolders, armyworms, white grubs, root aphids and leaf miners. Planting for example with the onset of the rainy season allows the plants to pass their juvenile stages before the pest mass arrival. Shifting planting times also results in growing the crop under different weather conditions.

***Synchronization of crops*** is another methods useful to break the cycle of many monophagous pests. In most cases insects have a new generation every 3-4 weeks, this means that if all the rice fields across a very wide area are left fallow for at least one month and then planted across the same period or have the same growth stage it is more likely that certain species make less damages: planthoppers, leafhoppers, stem borers, gall midge, leaf beetles, caseworms, and root weevils.

### *9.2.11 Trap Crop*

The trap crop technique works by attracting pests to a more attractive crop located around the production area. The size of the trap crop should be adequate to pull the pests away from the main crop but at the same time should not occupy much land, approximately 0.7 to 5.0%. The attractive plants should be given much more nitrogen fertilization to make their tissues tender for the pests. The control can be done either by manual removal of the eggs of pests or by chemical spray on the trap crop only.

### *9.2.12 Physical control*

Flooding stubbles in harvested fields when there is sufficient water helps to drown stem borers, armyworms, and grasshoppers. Prolonged flooding is required to full control pests that could find shelter and pockets of air in the stems. This practice is suitable for rice-fish as the aquatic animals can be left roaming the whole harvested field and continue to grow. Flooding also controls most of soil pest like white grubs, mole crickets, termites, and ants. Best results are achieved when the technique is done at community level to widen the area of pest control.

Tillage is an alternative method that can follow the flooding. It is very useful in agronomy as it enriches the soil with organic matter, crushes insects (stem borers, armyworm pupae, grasshopper eggs, black bugs and root weevils), destroys nests and exposes them to the sun and to the attack of predatory birds. Tillage has also another positive effect in preventing the regrowth of the stubbles (ratooning), thus breaking the cycle of gall midge, leafhoppers, plant hoppers and insect-vectored viral diseases such as yellow dwarf and tungro.

Fig. 80 Tillage buries crop residues and their pest, should be followed by flooding[14]

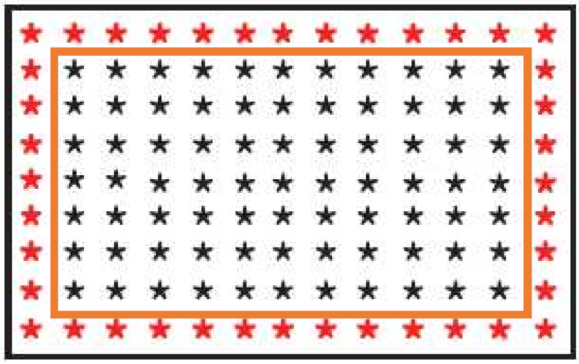


Fig. 81 Trap crops externally located (red) to paddy can be a good barrier against pests

Straw and stubble destruction was a common practice done through burning all crop residues. It was particularly effective for long-stemmed varieties that are no longer cultivated due to the abundance of the organic wastes. The practice is still in use in some countries, although restrictions may apply for the quality of the air. An alternative is to finely thresh the crop residues and to expose to the sun.

#### *9.2.13 Harvest Methods*

The way rice is harvested has sensitive implications in the control of the stem borer. In many areas rice is harvested by panicle removal, but this type of cutting allows 98% of the stem borer to survive by going deep into the remaining stem and get ready for the next crop. An efficient method would be to cut the stubble near the ground, but the efficiency in removal depends on the status of the larvae, that can survive if in diapause.

#### *9.2.14 Weed Control*

Presence of weeds need to be controlled due to the fact that many pests can use them to bridge in time and space between rice crops. Weeds are particularly important for leaffolders, leafhoppers, planthoppers, seed bugs, leaf beetles, black bug, mealy bug, armyworms, caseworms, root aphids, root bugs, root weevils, leaf miners, and seedling maggot. Tasks envisage the cutting of vegetation around paddies and the removal of weeds from inside the culture, the latter also with the support of fish, should the field be inundated.

### 9.3 Biological control

#### *9.3.1 Beneficial insects*

Use of parasitoids, predators are very effective to control population of pests. Parasitoids attack the eggs, larvae and pupae of the rice pests. Larval parasitism averages 40% in studies conducted on the

[14] Source: Islam, 2007

IRRI research farms. Predators are insects that actively attack the pest in their juvenile or adult stages. The wolf spider, *Lycosa pseudoannulata* is probably the most important predator in rice fields in Asia, but many other beneficials are important such as Damselflies, dragonfly, ladybug, etc.

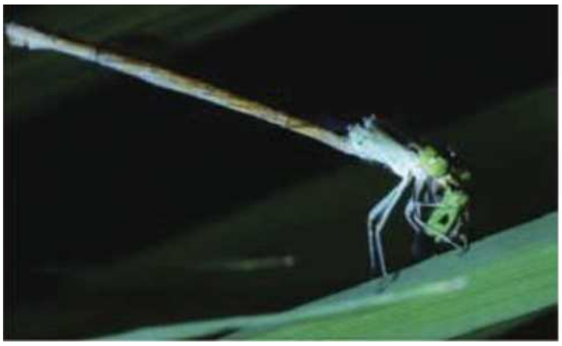


Fig.82 Damselflies eat leafhoppers[15]

Fig.83 wolf spider[16]

Fig.84 *Metioche vittaticollis* feeding on stem borer eggs[17]

Fig.85 Ladybirds eating stemborer eggs[18]

However it should be reminded that the beneficials are able to control but not to completely eradicate the pests, this because pests are their main source of food or reproduction and their complete disappearance eventually severely reduce the possibility of survival of the beneficial themselves.

Relying on biological control methods excludes the use of chemical products that are mainly large spectrum ones. Chemicals in fact do not differentiate between bad pests and beneficial and kill all insect indiscriminately. This, if treatments are done at the beginning of the growing season may bring negative consequences, as the absence of beneficials will favour successive infestations of pests with increased severity.

Use of products that are low impacting and do not affect the beneficials are therefore preferred within integrated pest management strategies.

## 9.4 Resistant cultivars

Resistant plants are seen as a good strategy for IPM in rice. Resistance is one of the objectives of plant breeders also in view of the cost-effectiveness of alternative control methods that are more expensive. Crops such as rice do not provide much profits, therefore the limited cash flow of farmers with small acreages and low technologies well suits the possibility to use cost-free remedies already included in the price of the seeds.

[15] Source: Ooi, 2015
[16] Source: Heinrichs, no date
[17] Source: Ooi, 2015
[18] Source: Ooi, 2015

## 9.5 Organic treatments

There are several products that are in use in organic agriculture and can be applied in integrated agriculture-aquaculture. However, it is important to remember that not all the products in use in organic agriculture are safe for aquatic animals due to the risks of cross toxicity. In some cases despite being organic some products are broad spectrum, which means that some beneficial insects may be affected thus preventing the crops to be fully protected in the successive stages.

In some cases products that are toxic for aquatic animals may be used if precautionary approaches are taken. In the case of rice-fish culture the drainage of the water, accompanied by the return of the fish in their refuges free the space for using such stronger organic treatments, also in consideration that the persistence of the vast majority of organic compounds in the environment is very short (2-3 days maximum) allowing the quickly return of fish in the field.

### *9.5.1 Toxins and beneficial microorganisms*

These compounds are obtained from nature and are safe for the fish. They can be either toxins obtained by microorganisms growing into the soil or fungus that targets the skin of the insects. The products are available in a miscible powder to be mixed with water under recommended dosages. The spores or toxins are sprayed to the vegetation, contaminate the bodies of the insects to successively germinate/penetrate and kill the host. In the case of toxins these are ingested by the pests. These products can be easily found all around in S.E. Asia, in some cases are also in commerce in Myanmar.

**Bacillus Thuringiesis (BT) -** Is a toxin extract from a bacterium that damages the insect's digestive tract and kills it. It can be sprayed on leaves and specifically targets caterpillars, leaf rollers, moth or butterfly larvae without damaging other beneficial insects. In particular for rice BT is effective against rice stem borers, rice water weevil. There are in commerce different strains with different levels of toxicity to the target pests.

**Spinosad** - Is a substance produced by a soil bacterium that has insecticidal effect to a broad range of pests such as clude thrips, leafminers, spider mites, mosquitoes, ants, fruit flies, etc. It is a combination of two different compounds called Spinosyn A and Spinosyn D. Spinosad works on the nervous system of the pests eating or touching the product causing uncontrolled flex of muscles, paralysis and eventually death within 1-2 days. The positive of the product is that it slightly penetrates in the vegetable tissues (semi-systemic), and is no or moderately toxic to fish at high water concentrations. The compound is degraded pretty fast, in water it degrades in 1 day under sunny conditions. With scarce light the products degrades in a very long time.

Fig. 86 bacillus thuringiensis[19]


Fig. 87 Spinosad

***Beauveria bassiana* -** Is a parasitic fungi that germinates grow and penetrates the insect's skin (chitin), killing the pests through dehydration/disease. It is effective against whiteflies, aphids, thrips, grasshoppers and certain types of beetles. It is no toxic to humans and has no withdrawal period.

[19] Source: http://npic.orst.edu/factsheets/btgen.html

***Metarhizium anisopliae*** – is a parasitic fungi that acts similarly to *Beauveria bassiana* by germinating on the insects' skin. It is a biocontrol agent of termites, mosquitoes, beetles, and grasshoppers.

Fig. 88 Beauveria bassiana[20]

Fig. 89 Metarhizium anisopliae[21]

There are other fungal or microbiological pest control agents of more difficult availability such as *Zoophthora radicans*, a disease-causing agent in insects; *Nomuraea rileyi*, an effective fungus against rice caterpillars; *Hirsutella citriformis* a fungus active against hoppers.

### *9.5.2 Plant insecticides*

Some plants extracts have some bland insecticidal properties whose characteristic is the very short persistence due the quick degradation operated by the sunlight. In general the lifespan of the compound is no longer than 2-3 days, therefore treatments should be done in the evenings to let the compound act in darkness and thus have its effectiveness maximized. In most of the cases these organic insecticides are toxic to fish and spraying, if necessary, should occur with fish away, ideally with the paddy in dried conditions. Fish can then return after the adequate withdrawal period is observed.

**Azadiractin/neem** – neem oil is largely used in organic agriculture in Asia. The compound causes insects to reduce or cease feeding, can prevent larvae from maturing, reduces or interrupts mating behavior and, in some cases, the oil coats the breathing holes of insects and kills them by suffocation. Azadirachtin is the active ingredient contained in neem oil that is extract and sold in acqueous solution. Compared to the neem oil it is more concentrated and does not make oily films in the water. It is known to affect a broad spectrum of over 200 insect species including aphids, mealybugs, caterpillars, Japanese beetle, whiteflies, mites, root aphids and thrips. It is an anti-feedant, but it also disrupts normal insect growth/molting. The product is also toxic to fish, therefore treatments must be performed away from fish, ideally with dry field conditions.

**Pyrethrum** - is the extract of a flower *Chrysanthemum cinerariaefolium* it is a natural neurotoxic insecticide, broad spectrum that also kills beneficial insects. Its use may be considered only in case of extreme infestations. It is toxic to fish, it may be used as foliar treatment in dry conditions or away from water. Pyrethrum has low persistence, it is easily destroyed with light in 1-3 days.

**Nicotine** – it is the aqueous extract of tobacco, the natural version of synthetic neonicotinoid largely in use in agriculture. It is a neurotoxic broad spectrum insecticide. It is a remedy for a range of pests, including whiteflies, gnats, root and leaf aphids, thrips and leafminers. It can be used in cases of severe infestation of some plants. Nicotine sprays are also toxic to fish so its use should be done in dry field conditions with absent fish. The return of the fish will occur after a proper period of time.

[20] Source: https://www.researchgate.net/figure/Adult-cabbage-fly-Delia-radicum-killed-by-Beauveria-bassiana-This-fungus-produces_fig1_291302201 (courtesy J. Eilenberg)

[21] Source: https://www.scienceimage.csiro.au/library/insects/i/1253/greyback-cane-beetle-larva-infected-with-metarhizium/



Fig. 90 Neem | Fig. 91 Pyrethrum | Fig. 92 Nicotine extract from tobacco[22]

*9.5.3 Plant extracts*

**Garlic oil** - Insecticidal properties which are enhanced if mixed with oil and soap. It is active against aphids, leafhoppers, whiteflies, some beetles and nematodes. Dissolve minced garlic in vegetable oil and steep for one or more days. After filter the oil and mix in water added with soap to solubilize the oil.

**Chili oil** – it combines the insecticidal effects of the oil with the repellent effect of the chili. Large quantities of very hot chili are left in oil jars for many days in the darkness. The amount of chili to be used is such to avoid any void in the container with the oil. The resulting oil, turned red in colour, is filtered and the dissolved in water at 2.5% concentration by also adding soap to make it soluble. Add and mix sufficient soap in the water until the oily film in the surface of the water disappears.

**Essential oils** – citronella, sage, thyme, rosemary oil or many others. They are pest repellent and reduce the levels of feeding damage. They cover a broad range of pests. Oil can be sprayed alone, by mixing small quantities in water with small amounts of soaps to make them soluble, or can be mixed with other products (e.g. insecticidal soaps).

**Tomato leaves extract** – tomato belongs to the same family of tobacco, which contains nicotine used to kill insect in a broad spectrum manner. Tomato also contains some similar compounds that are moderately toxic to the insect, thus acting as a bland insecticide. It acts against aphids, earworm. The extract is also attractant of beneficial insects. The preparation is made by taking equal weights of fresh tomato plants and water and keep in the water away from light for 12 hours. Threshed plants parts/leaves have better dissolving effects. Water is then filtered and sprayed thoroughly to the plants.

*9.5.4 Other products*

**Insecticidal soap** - is strictly for use on soft-bodied insects. The soap is made of potassium salts of fatty acids and is completely natural. It can be mixed with essential oils to also add repellent properties. Soap attacks the skin of the insects that eventually die for dehydration. Soaps work well on common pests like aphids, lacebugs, mealybugs, mites, leaf hoppers, scale insects, spider mites, thrips and whiteflies. Soaps will kill soft-bodied nymphs (an immature life stage) but it won't damage hard eggs, therefore the treatments should be repeated to control the next generation before they get maturity and reproduce.

**Vegetable oils** – are widely in use in organic agriculture. The mechanism of action is to suffocate the pests by covering their bodies with a tiny film of oil thus making them impossible to breathe air from their skin. Oils are effective against aphids, mealybugs, mites, scales. Spray on a 2.5% concentration

[22]Source: https://www.britannica.com/science/nicotine

(0.5 L in 20 L of water) by also adding adequate amount of soaps to make the oil soluble. Add and mix sufficient soap in the water until the oily film in the surface of the water disappears.

**Sulphur** - powdered or lime sulphur. It is an inorganic product, widely in use in organic agriculture. It is used as pest repellent and is an effective insecticide against mites. It can also be used as fungicide with very good results. It is not particularly toxic to fish, although precautionary approaches should be considered by not exceeding with dosages and treatments.

**Lime/ash** – is a repellent that covers a broad range of pests. Finely sieve the ash and blow on wet leaves using a duster.

Fig. 93 Insecticidal soap

Fig. 94 vegetable oil

Fig. 95 ash

## 9.6 Chemical Control

The use of chemical insecticides was established in the sixties as part of the green revolution program to increase productivity.  However the insecticides show some drawbacks due to the costs of the products/equipment and the needs to repeat the treatments despite the low profit margins achievable for some crops. As already explained chemical products are in most of the cases large spectrum, which means that each treatment not only kills pests, but also the beneficial insects that predate on pests, thus free the field for the successive and stronger attacks by the same insects.

In the case of rice-fish the presence of the aquatic animals severely limits the possibility to use these synthetic products due to toxicity and risks of accumulations in the food chain. Although different fish species may have different resistance, their threshold to toxicity is almost very low and strategies aiming at confining fish in enclosures during the treatments to free them afterwards may always have percentages of risk. This is much more accentuated by the long persistence of synthetic compounds, which can be enhanced in aquatic environments.

The use of chemical might be however tolerated to treat surrounding environments to the paddy fields or as a strategy in trap crops, as explained earlier. Trap crops are intentionally planted with very susceptible species or varieties that attract pests. The attractiveness could be also enhanced by supplying large quantities of nitrogen to make the plants more appetizing. Pest move to the trap crops and then can be controlled by very limited amount of chemicals carefully sprayed to avoid any contamination.

## 9.7 Key aspects in integrated pest management

Integrated management focuses on the synergic use of different strategies to control pests. This includes the presence of beneficial insects that should not be harmed by generalized treatments. One important aspect to take into account, particularly when organic or chemical remedies are used, is the build-up of resistance against substances that are meant to kill pests. Most of the time the resistance is caused by not appropriate farm managements, where the constant use of the same product over many crop cycles makes it easier for the pests to bypass the toxicity by simply benefitting by genetic selections of individuals. To avoid such problem it is always important to rotate the products/treatments so that it would be much more difficult for the pests to build tolerance.

Organic management, contrarily to chemical treatment, is preventive and its efficacy to control pests is highest when infestations are not widespread. This means that farmers should constantly monitor for any sign of problems and take up the necessary measures to contrast the insurgence of pests in their crops after carrying out a cost-benefit analysis on the convenience of the treatment vs the potential losses. The vast majority of the treatments in organic pest management is by contact. There must be indeed a physical interaction between the product (soap, oil, plant extract insecticide, etc) and the pest, although this is less important with fungal insecticides whose spores enter in contact with moving insects. These aspects add some complications when there is the need to treat the downward parts of the leaves, which forces to use quality sprayers that are able to micronize the droplets of water in a way to make a tiny fog that can penetrate much more easily the canopy.

## 9.8 Incidence of pests in Myanmar

Despite the presence of risk areas where pests have a big impact due to the presence of favourable environmental conditions or managerial issues the majority of the country is apparently not experimenting critical conditions. This may in part due to the particular farm management that sees monsoon rice followed by fallow periods or intercropping with beans/grams, the limited use of nitrogen fertilizers, the high number of cattle grazing on crop residues and the practice of burning the field before the new season commences. A past survey carried out at nationwide level in Myanmar (Naing et al 2008), suggests how the presence certain pests is strictly affected by climate. In the specific case of the rural area it appears that stem borer is not impacting the farms heavily, while rice gall midge had a higher incidence.

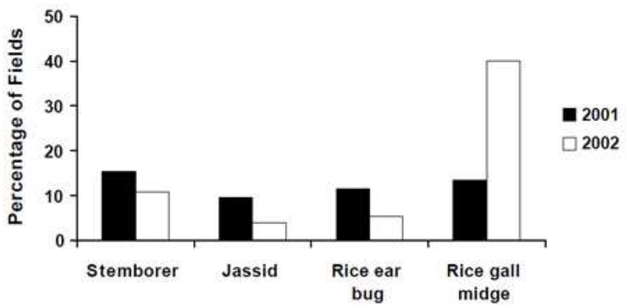



Fig. 96 Incidence of pests in Myanmar (Source: Naing et al 2008)

In the past rice gall midge incidence was limited in the country, however the changes in climate and weather patterns may have favoured the spread of specific pests. In the case of the survey the outbreak seemed caused by infested seedbeds. Control in all the steps and particularly at nursery stage is fundamental to avoid the introduction of undesired insects into the rice fields. Agronomic practices, flood and drain and the control by fish of insect that use the water media to move is essential to keep the level of infestation below the level of damage.

## 10. Disease control

Disease in rice can have a considerable impact on productivity. The main causes of diseases are bacteria, fungi, and viruses mainly transmitted by vectors. The incidence of diseases depends on three factors whose combination could either favour or limit the outbreaks: the plants and their health, the characteristics of the pathogen and the environmental conditions such as climate, temperature, humidity, and nutrition.

### 10.1 Disease control with fish

Finfish play an important role in controlling the pathogens in the water by actively removing affected tissues, thus disturbing the growth and maturation of the infections agents. The grass carp *C. idellus* was noted to be able to control rice sheath blight disease if the infection was located at water level. The incidence of the disease could be lowered by 10-20% at least. The strategies used to reduce the incidence of the diseases are (Yu et al, 1995; Xiao, 1992):

- removing diseased tissues at the bottom of the plants,
- eating pathogen structures (fungal sclerotia)
- producing secretions that slow down the progression of the infection
- improving ventilation and light penetration to build a microclimate that is unfavourable to the pathogens,
- maintaining deep water conditions that prevent the germination of the spores

### 10.2 Strategies in crop protection

#### *10.2.1 Plant resistance and health*

On the plant side one of the most effective strategies is to use varieties that are genetically selected for resistance to specific pathogens or vectors. Another factor can be also the tolerance to higher/lower temperatures or salinity, which reduces the stress and thus the susceptibility of the plants to the pathogen. The use of certified seeds, also treated with fungicides, avoids the risks to bring in the seedbeds and in the field the pathogens that may be carried in seeds that are not disease-free.

When possible the thermal treatment of the seeds before germination would be a cost-effective strategy to kill pathogenic bacteria.

#### *10.2.2 Environmental conditions*

Most of the time pathogens are present in the environment, but their mechanism of actions are inhibited by environmental conditions or factors that are not favourable to their quick diffusion. In many cases temperatures and humidity are the key determinants in disease outbreaks, however farmers have little control on the climate in outdoor conditions. However, much can be done to reduce the humidity or heat within the crop through proper spacing to let the wind and the light penetrate the canopy. More wind and light keep the leaves dryer, provide good light conditions for the optimal growth of the plants and avoid competition for light among plants that would eventually make their tissues softer. Softer tissues are very negative because the plants can oppose less resistance to the pathogens.

#### *10.2.3 Optimal nutrition*

A healthy plant is less prone to get diseases because is more resistant. In the previous pages the effect of excessive nitrogen was already described as negative to the plants because plants are favoured to grow fast, without hardening their tissues, a condition that is essential to oppose much more resistance against pathogens. On the other hand potassium has the capacity to slow down the growth and let the plant build stronger wall structures if calcium is also supplied in equal measures. Among other key nutrients zinc is also important to provide a non-specific protection to the plants, boron reduces the severity of many diseases because of the function that it has on cell wall structure while silicon is essential to build strong walls and makes it difficult to the fungi to penetrate.

Fig. 97 Optimal spacing for healthy growth

+Zinc
+Potassium
- Nitrogen
+Boron
+Silicon
+Calcium

Fig. 98 Optimal nutrition to improve resistance

### *10.2.4 Control of vectors and wild vegetation*

Many hoppers, aphids are the responsible agents of the transmission of viruses to the rice plants. Insect may thrive in local wild vegetation, or on the crop residues, regrowth of the rice hills, etc. Therefore it is indispensable to reduce as much as possible the presence of these pests and the wild vegetation that is responsible to host the viruses. Control techniques have been described in the previous parts and encompasses the need to clean the field after harvest, plough the residues into the soil, flood the fields, and control the weeds.

## 10.3 Chemical treatments

Although not very compatible with fish productions the use of chemicals may be required to save crops under severe attack. Regardless the type of production (rice only or rice-fish) it must be said that preventive management is fundamental to avoid risk of diseases and to afford expensive treatment costs that would reduce profitability. The choice of rice-fish should also consider the pest and disease occurrences, since areas at high risk may not find the polyculture with aquatic animals convenient.

On the contrary specific designs of rice-fish systems could be more suitable, as fish could be compartmented in separated areas in case that any type of intervention on the rice field was needed (e.g. drying/flooding cycles for pest management purposes, treatments, etc.).

References on the type of chemical compound needed for specific diseases are in Annex 4.

## 10.4 Organic management

There are different products that are compatible with fish and in many cases even used for aquaculture. Strategies could consists in the treatment of seeds/seedlings when they are in the growing bed, or timed treatment when first symptoms of pathogen arise in the field.

***Trichoderma*** - is a fungus potent biocontrol agent and is used extensively for soil borne diseases. Its mechanism of action is basically predatory, with the fungus attacking the pathogen and destroying it. It has been used successfully against pathogenic fungi belonging to various genera: *Fusarium*, *Phytopthora, Scelerotinia*, *Pythium* etc. *Trichoderma* has uses as biological control agent against *Rhizoctonia solani*, rice brown spot. *Thrichoderma* has a broad spectrum of action and can be used to the different parts of the plants indiscriminately. The fungus is completely safe for the fish and does not raise any food safety issues of accumulation. The product is largely in use most countries of the world and other ASEAN countries, it is also available in Myanmar.

***Bacillus subtilis*** – it is a microorganism that has several beneficial attributes:

- biocontrol,
- plant growth promotion,
- phosphorus (P) solubilisation

In aquaculture it is also used as a probiotic in association with yeasts (*Saccaromices* sp.) and lactobacillus and organic enzymes to improve the health of the fish and at the same time to process the organic sediments accumulating with fish wastes in order to create healthier ponds (Fig. 101).

The *B. subtilis* strains inhibits *Fusarium oxysporum* (25–34%) and *Pythium, Rhizoctonia* and *Sclerotium*. Fungi and some diseases such as rot disease, dryness, rust disease, usually live on the bottom of the leaves and fruit, therefore it is important to guarantee an optimal wetting in the plants parts exposed to the pathogens. The product is largely in use in Thailand and other ASEAN countries, but also available in Myanmar.

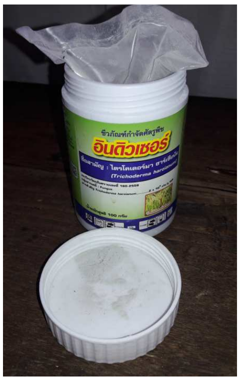


Fig. 99 Trichoderma

Fig. 100 Bacillus subtilis

**Other microorganisms** – like the integrated pest management there are many natural predators of pathogens that can raise the resistance of the plants. *Agrobacterium radiobacter, Streptomices griseoviris, Coniothyrium minitans, Verticillium biguttatum, Rhizoctonia* spp. However for not all these beneficial organisms there is already a ministerial license in every country.

**Potassium bicarbonate** – it is a very safe product to be used. It modifies the environmental conditions on the surface of the leaves/plant by shifting the pH parameters, which will become no longer optimal for the pathogen. The spraying to the aerial part of the plants (leaves) is also beneficial because it brings immediate absorption of potassium by the leaves, which helps to quickly raise their resistance against the pathogens.

**Sulphur** – has a broad spectrum of action against the fungal diseases. In some cases sulphur is also used as an insecticide against mites. For the dosages used it is not harmful to fish, considering the volume of the water body where they are farmed.

**Copper** – it is used also in aquaculture to disinfect the fish against fungal diseases. The spectrum of action of copper is wide. However attention should be put to avoid accumulation in the ecosystem, as higher concentrations may disrupt some physiological processes in aquatic animals. There are different types of products available that help to reduce the dosages to the plants: from copper sulphate, the typical product used in organic agriculture, to copper hydroxide, which requires concentrations much smaller to be effective.

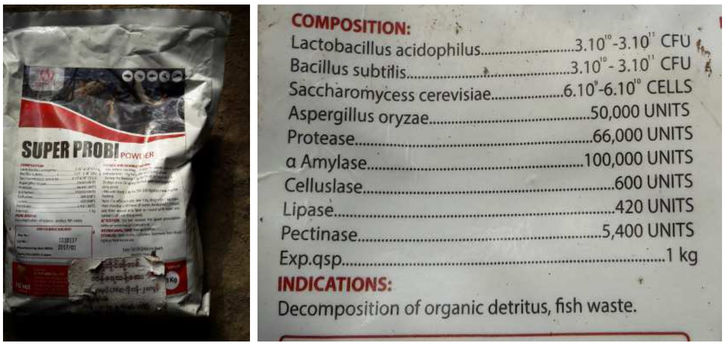



Fig. 101 Probiotics for aquaculture contain microorganisms also useful against fish diseases and enzymes to dispose wastes


Fig. 102 Potassium bicarbonate product in commerce

## 10.5 Incidence of rice disease in Myanmar

A past survey carried out at nationwide level in Myanmar (Naing et al 2008), outlined the types of diseases that mainly affected the rice farming in the country:

- Bacterial leaf blight BLB (caused by *Xanthomonas oryzae* pv. oryzae)
- Sheath rot (caused by *Sarocladium oryzae*)
- Rice sheath blight (caused by *Rhizoctonia solani*)
- False smut (caused by *Ustilaginoidea virens*)
- Ufra disease, caused by the rice stem nematode, *Ditylenchus angustus*, is the most important disease of deep-water

Like for pests the changes in climatic and environmental conditions should have an impact on the incidence of specific diseases due to the more favourable conditions for pathogens. Knowledge of the characteristics of each pathogen and the agronomic measures that can be put in practice can help to control in more efficient ways the risk of insurgence of diseases in the rice.

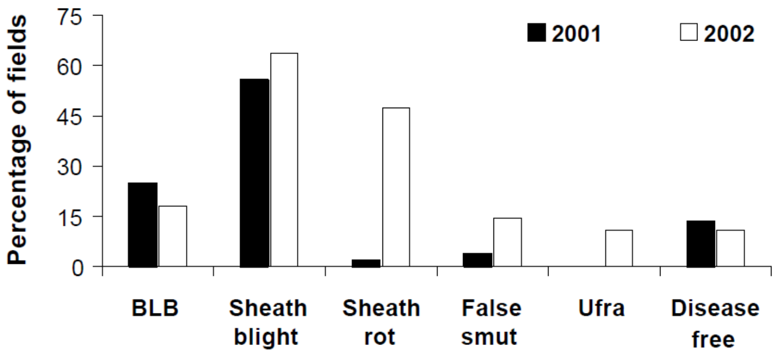



Fig. 103 Incidence of diseases in Myanmar (Source: Naing et al 2008)

## 11. Conclusions

The farming of rice and fish shows advantages that overcome the possible drawbacks. Progressive losses of profitability in rice farming need strategies that help to maintain or increase livelihood opportunities to farmers without denaturalizing lands from their original productions.

The presence of fish is seen by a percentage of farmers as a constraining factor that limits their choices to grow efficiently staple crops, also with the use of chemical products that may be harmful to fish. However proper management of crops with good agronomic practices and integrated pest and diseases management, also including biologic defence strategies, could greatly reduce production losses. Nevertheless different rice-fish designs can be used even by conventional farmers who do not want quit the use of chemicals by simply decoupling the fish and rice areas.

In the vision of climate change it is important to use natural resources in the best effective ways. The development of strategies involving the use of crop/animal wastes for fertilization, the use of livestock, beneficial insects and microorganisms for controlling pests and diseases are very important approaches for more sustainable and smarter agriculture.

Such strategies, combined with alternative approaches in rice culture that reduce the impact on greenhouse gas emissions and make better use of wastes and water by combining aquaculture and agriculture can help to boost productivity in rural areas and prevent local communities to abandon their lands in search of better incomes.

Nevertheless the technical support and innovations should be accompanied by upgrades of policies and governance to favour integrated management and synergic uses of natural resources.

## 12. References


Abbas Hameed. K. 2018. Initiative of the System of Rice Intensification. 2nd International Symposium on Agroecology: Scaling Up agroecology to achieve the Sustainable Development Goals. Food and Agriculture Organization of the United Nation. Rome, Italy http://www.fao.org/3/CA0640EN/ca0640en.pdf

Bayer, 2019. *Lissorhoptrus oryzophilus*. Bayer crop science. https://www.cropscience.bayer.com/en/crop-compendium/pests-diseases-weeds/pests/lissorhoptrus-oryzophilus

Bunch, T. R.; Bond, C.; Buhl, K.; Stone, D. 2014. Spinosad General Fact Sheet; National Pesticide Information Center, Oregon State University Extension Services. http://npic.orst.edu/factsheets/spinosadgen.html

CABI 2019, *Lissorhoptrus oryzophilus* (rice water weevil). invasive Species Compendium Detailed coverage of invasive species threatening livelihoods and the environment worldwide https://www.cabi.org/isc/datasheet/30992#tosummaryOfInvasiveness

Costa-Pierce, B.A. 1992. Rice-Fish systems as intensive nurseries, p. 117-130. In C.R. De la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Dela Cruz, C., 2001. Rice-fish systems in Indonesia. Integrated agriculture-aquaculture. In: Integrated agriculture-aquaculture a primer. FAO Fisheries Technical Paper 407. Food and Agriculture Organization of the United Nations http://www.fao.org/3/Y1187E/y1187e19.htm#w

Dela Cruz, C. Sevilleja, R.C. and Torres,J. 2001. Rice-fish systems in Guimba, Nueva Ecija, Philippines. In: Integrated agriculture-aquaculture a primer. FAO Fisheries Technical Paper 407. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/Y1187E/y1187e24.htm#bb

FAO 2016 Higher yields from healthy plants in healthy soil. Save and Grow Farming Systems fact sheet 2. Plant Production and Protection Division Food and Agriculture Organization of the United Nation. Rome, Italy http://www.fao.org/3/a-i5305e.pdf

Gupta, M.V., J.D. Sollows, M. Abdul Mazid, A. Rahman, M.G. Hussain and M.M. Dey. 1998. Integrating aquaculture with rice farming in Bangladesh: feasibility and economic viability, its adoption and impact. ICLARM Tech. Rep. 55, 90 p.

Halwart, M., Gupta, V.2004. Culture of fish in rice fields. FAO- WorldFish Center. http://www.fao.org/3/a-a0823e.pdf

Heinrichs, E.A. (no date). Management of Rice Insect Pests. Radcliffe's IPM World Textbook. CFANS. https://ipmworld.umn.edu/heinrichs

IRRI, (no date) Diseases. Rice Knowledge Bank. http://www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/diseases

IRRI, (no date) Insects. Rice Knowledge Bank. http://www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/insects

Islam, Z. 2007. Control of rice insect pests. IRRI Rice Knowledge Bank. http://www.knowledgebank.irri.org/ericeproduction/PDF_&_Docs/Control_of_rice_insect_pests.pdf

Kawamura, K., Ikeura, H., Phongchanmaixay, S. Khanthavong, P. 2018, Canopy Hyperspectral Sensing of Paddy Fields at the Booting Stage and PLS Regression can Assess Grain Yield. Remote Sens. 2018, 10, 1249. https://www.mdpi.com/2072-4292/10/8/1249

Kutty, M.N. 1987. Fish Clture in Rice Fields. UNDP, FAO and Nigerian Institute for Oceanography and Marine Research, Project RAF/82/009. http://www.fao.org/3/AC180E/AC180E00.htm

Li, K. and Y. Pan. 1992. Rice fields as fish nurseries and grow out systems in China, p. 151-164. In C.R. De la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fi sh research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Mackay, K.T., 1995. Rice-fish culture in China. International Development Research Centre. https://www.idrc.ca/sites/default/files/openebooks/313-5/index.html#page_3

Miao, 2009. W. China: A holistic Approach for livelihood improvement in Rural Areas. In: De Silva, S.S. & Davy, E.B, Success Stories in Asian Aquaculture. NACA Network of Aquaculture Centres in Asia Pacific. pp 15-40

NACA, 1986. A Review of Rice-Fish Culture in China. NACA/WP/86/30 http://www.fao.org/3/ac221e/ac221e00.htm

Naing, T. A. A., Kingsbury, A. J., Buerkert, A. and Finckh, M. R.2008. A Survey of Myanmar Rice Production and Constraints. Journal of Agriculture and Rural Development in the Tropics and Subtropics 109:151–168

NZ Herald 2018. Cow pee: 200 tonnes of nitrogen leaching each day. https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12040194

Ooi, P.A.C. 2015. Common insect pests of rice and their natural biological control. Agriculture Science Journal. UTAR Agriculture Science Journal Vol 1:49-59 http://eprints.utar.edu.my/1681/1/UASJ_2015_Vol_1(1)%2C_10_Common_Insect_Pests_of_Rice_and_their_Natural_Biological_Control.pdf

Quyen, M.V., L.T. Duong, D.K. Son, P.N. Minh and N.D. Nghia. 1992. Rice fi eld aquaculture systems in the Mekong Delta, Vietnam: potential and reality, p. 105-115. In C.R. de la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

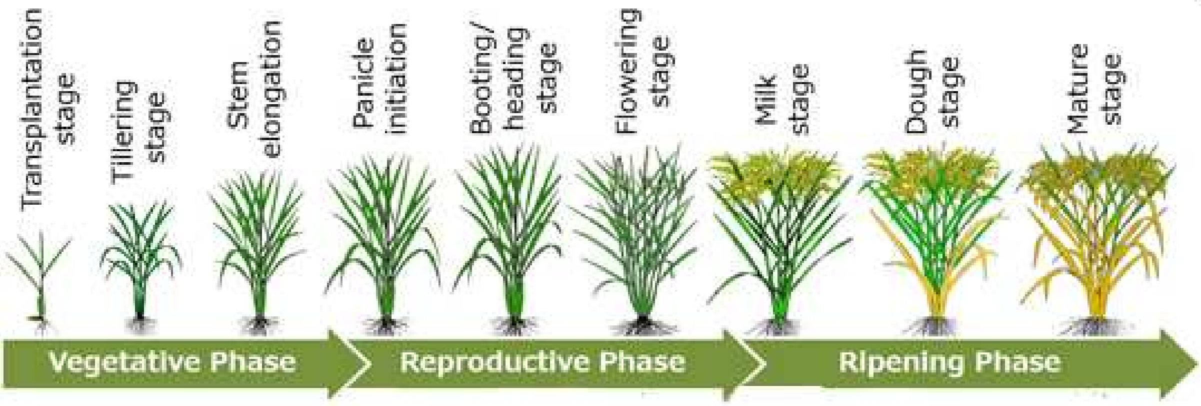
Sevilleja, R.C. 1992. Rice-fish farming in the Philippines: past, present and future, p. 77-90. In C.R. De la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

UAEX 2017.Using Alternate Wetting & Drying (AWD) Rice Flood Management Division of agriculture Research & Extension. University of Arkansas System. https://www.uaex.edu/farm-ranch/crops-commercial-horticulture/rice/2017%20Alternate%20Wetting%20and%20Drying%20Rice%20Management.pdf

Xiao, Q.Y. 1992. Role of fish in pest control in rice farming, p. 235-244. In C.R. De la Cruz, C. Lightfoot, B.A. Costa- Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc.24, 457 p.

Yu, S.Y., W.S. Wu, H.F. Wei, D.A. Ke, J.R. Xu, and Q.Z. Wu. 1995. Ability of fi sh to control rice diseases, pests, and weeds, p. 223-228. In K.T. MacKay (ed.) Rice-fi sh culture in China. International Development Research Centre (IDRC), Ottawa, Canada, 276 p.

## Annex 1
## Growth stages of rice[23]




**Transplantation stage**
Seedling of few days are transplanted into the rice field

**Tillering stage**
Shoots from a single plants come out from the root zone resulting in a batch of plants (hill) originated from a single one

**Stem elongation**
The rice plants start to become taller, plants use more nitrogen at this stage

**Panicle initiation**
An initial widening of the tip of the plant is seen

**Booting/heading stage**
The tip of the developing panicle emerges from the stem and continues to grow
Rice is said to be at the 'heading' stage when the panicle is fully visible

**Flowering stage**
Flowering begins after the panicle well completed its growth

**Milk stage**
The grains start to grow, if squeezed the grain take out a milky liquid

**Dough stage**
The grains continue to grow, if squeezed the grain take out a creamy material, the plant starts to yellow

**Mature stage**
The grains are mature and hard and cannot be squeezed. The plant continue to yellow

[23] Source: Kawamura et al.,2018 https://www.mdpi.com/2072-4292/10/8/1249

## Annex 2
### Toxicity levels of chemical products in use for rice culture

**Median tolerance limits (TLM) of common carp (*Cyprinus carpio*) to various pesticides**

| Formulated Product | * | Toxicity grade |
|---|---|---|
| **INSECTICIDE** | | |
| Trichlorfon | 6.2 | medium |
| Dichlorvos | 4.0 | medium |
| Fenitrothion | 4.4 | medium |
| Malathion | 9.0 | medium |
| Rogor | <40.0 | low |
| Methyl Parathion | 5.0 | medium |
| Phosmet | 5.3 | medium |
| Phenthoate | 2.0 | medium |
| Baytex | 2.0 | medium |
| Tsumacide | 15.3 | low |
| Landrin | 38.1 | low |
| Bassa | 12.6 | low |
| Etrofolan | 4.2 | medium |
| Chlordimeform | 15.2 | low |
| Rotenone | 0.032 | high |
| Bramaxymil octamoate | 0.0 | high |
| **BACTERICIDE** | | |
| EBP | 5.0 | medium |
| IBP | 5.1 | medium |
| Edinphensop | 1.3 | medium |
| Oryzon | 6.7 | medium |
| Plictran | 14.6 | low |
| Thiophanate methyl | 11.0 | low |
| Blasticidin | >40.0 | low |
| Kasugamycin | 100.0 | low |
| CAMA | 10.0 | medium |
| Phenazine | >10.0 | low |
| Triram | 4.0 | medium |
| **HERBICIDE** | | |
| 2,4-D | >40 | low |
| DMNP | 14.0 | low |
| Propanil | 0.4 | high |
| Nitrofen | 2.1 | medium |
| Benthiocarb | 3.6 | medium |
| Amine methanearsonates | 3.7 | medium |
| GS 13633 | 0.86 | high |
| **Formulated Product** | **TLM (ppm) 48-hours** | **Toxicity grade** |

| | | |
|---|---|---|
| Hedazhuang | 34.0 | low |
| Oradiazon | 3.2 | medium |
| Prometryne | 23.5 | low |
| Glyphosate | 119.0 | low |
| Pentachlorophenol | 0.35 | high |
| **OTHERS** | | |
| Zinc Phosphide | 80.0 | low |
| Propargit | 1.0 | medium |
| Lime | 140.0 | low |

* Low TLM values means that the product is very toxic, very high values means the product has low toxicity

(Modified from Xiao 1992)

## Annex 3
## Pests in rice[24]

**Black bug** *Scotinophara coarctata*, Pentatomidae, Hemiptera

**Impact**

- Pests feed on plant from seedling to maturity. Ten adults per hill can cause losses of up to 35% in some rice

**Prevention**

- Resistant varieties.
- Maintain a clean field by removing the weeds and drying the rice field after plowing.
- Plant rice varieties of the same maturity date to break the insect's cycle.
- Encourage biological control agents

**To control infestation**

- Flood the fields. This can cause higher egg mortality.
- After harvest, plow fields to remove remaining insects.
- use of fungal insecticide (beauveria, metarhizium), use of neem

**Leafhoppers** *Nephotettix* sp. Cicadellidae, Hemiptera

**Impact**

- Green leafhoppers are vectors of viral diseases such as tungro, yellow dwarf, yellow-orange leaf, transitory yellowing, and dwarf

**Prevention**

- Resistant varieties

---

[24] Sources:
Rice Knowledge Bank http://www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/insects
Islam, Z. 2007 Control of rice insect pests IRRI Rice Knowledge Bank. http://www.knowledgebank.irri.org/ericeproduction/PDF_&_Docs/Control_of_rice_insect_pests.pdf
Ooi, P.A.C. 2015. Common insect pests of rice and their natural biological control UTAR AGRICULTURE SCIENCE JOURNAL VOL. 1 Agriculture Science Journal. http://eprints.utar.edu.my/1681/1/UASJ_2015_Vol_1(1)%2C_10_Common_Insect_Pests_of_Rice_and_their_Natural_Biological_Control.pdf

- synchronized crop
- transplant old seedling
- Plant early particularly in the dry season to reduce the risk of insect-vector disease.
- Avoid planting during the peak of green leafhoppers activity
- Apply nitrogen as needed, do not exceed
- Control weeds in the field and on the bunds
- Perform crop rotation
- Intercrop upland rice with soybean to reduce the incidence of leafhoppers on rice
- use of fungal insecticide (beauveria, metarhizium)

**Plant hopper** *Nilaparvata lugens*, Delphacidae, Hemiptera; *Sogatella furcifera*, Delphacidae, Hemiptera

**Impact**

- Feeding damage results in the yellowing of the plants
- crop loss may be 100%

**Prevention**

- Outbreaks result from pesticides destroying natural enemies
- Remove weeds from the field and surrounding areas
- Use a resistant variety
- Look for PH daily in the seedbed and field
- Use light traps
- Flood the seedbed, for a day
- Sweep small seedbeds with a net to remove some BPH (but not eggs), particularly from dry seed beds
- Use natural enemies
- Only apply insecticides to the seedbed when there is more than 1 planthopper for rice, of if there are more pest than beneficial insects or when it is not possible to flood the field
- use of fungal insecticide (beauveria, metarhizium)

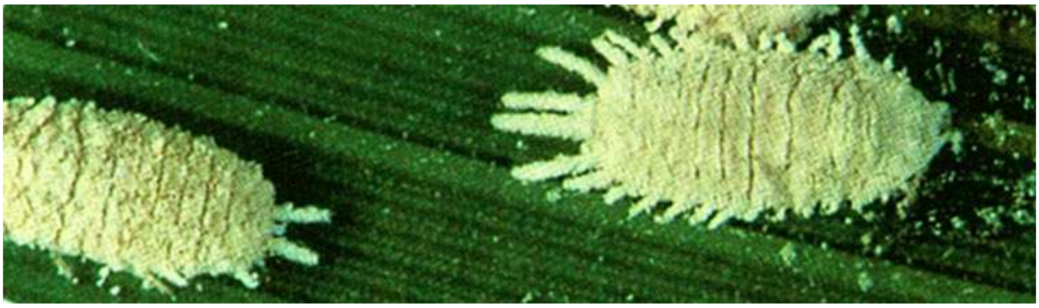
**Stem borer** *Scirpophaga* sp. Pyralidae, Lepidoptera, *Sesamia inferens*, Noctuidae, Lepidoptera

**Impact**

- Excessive boring through the sheath can destroy the crop
- can reduce the number of reproductive tillers
- can cause yield loss of about 20-30%

**Prevention**

- Use resistant varieties
- Handpick eggs in the seedbed
- Raise level of water periodically to submerge the eggs deposited on the lower parts of the plant
- Before transplanting, cut the leaf-top to reduce carry-over of eggs from seedbed
- synchronous planting
- harvest crops at ground level to remove the larvae in stubble
- remove stubble and volunteer rice, plow and flood the field
- Encourage biological control agents
- Bacteria and fungi also infect the larvae
- Apply moderate nitrogen fertilizer and in split
- Use *Bacillus thuringiensis*



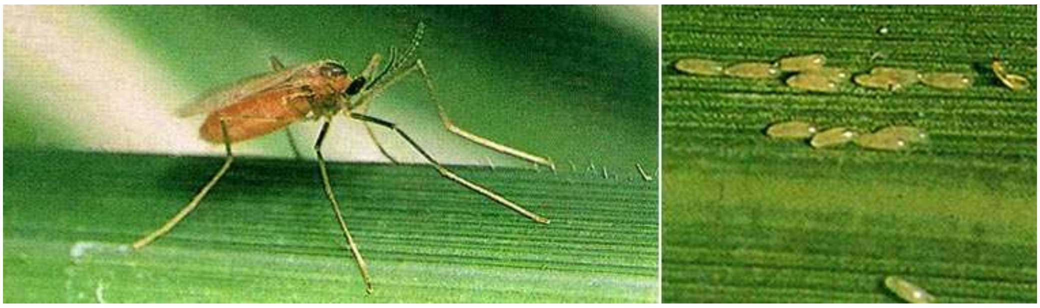
**Rice mealybug** - *Brevennia rehi*. Pseudococcidae, Hemiptera.

**Impact**

- high population of the pest can cause yellowing and stunting of the crop
- heavy losses to crops in Bangladesh, India, and Thailand. High pest density (>100 mealybugs/hill) can cause plants to wilt and die

**Prevention**

- Encourage biological control agents
- Insecticidal soap (need to spray on their bodies to kill)



**Rice gall midge** *Orseolia oryzae* Diptera, Cecidomyiidae

**Impact**

- forms a tubular gall at the base of tillers, causing elongation of leaf sheaths

- Can cause significant yield losses of 30–40%

**Prevention**

- Use resistant varieties
- Plow ratoon of the previous crop and remove all off-season plant hosts
- Encourage biological control agents
- use of fungal insecticide (beauveria, metarhizium)

**Rice skipper** *Pelopidas mathias*, *Parnara guttata.* Lepidoptera, Hesperiidae

**Impact**

- considered as a minor pest in rice

**Prevention**

- Biological control
- *Use Bacillus thuringiensis*

**Rice leaffolder** *Cnaphalocrocis medinalis* Pyralidae, Lepidoptera

**Impact**

- damage caused by leaffolders may be important when it affects more than half of the flag leaf
- when leaffolders infest at reproductive phase, the damage can be economically important
- High feeding damage on the flag leaves can cause yield loss

**Prevention**

- Use resistant varieties
- Follow rice with a different crop, or fallow period
- Avoid ratooning
- Flood and plow field after harvesting
- remove grassy weeds from fields and borders.
- Reduce density of planting
- Use balanced fertilizer rates
- Use organic insecticides *Bacillus thuringiensis*

**Rice caseworm** *Parapoynx stagnalis.* Lepidoptera. Pyralidae

**Impact**

- cause patches of severe defoliation that results in stunted growth and death of plants
- plants can recover from the damage if there are no other defoliators present. However, maturity may be delayed

**Prevention**

- Use of correct fertilizer application.
- Plant early and use wider spacing (12 × 08 inches)
- Drain the field
- Transplant older seedlings. Sparse planting can also reduce the damage.
- Grow a ratoon
- biological control agents
- use Bacillus thuringiensis

**Rice thrips** *Stenchaetothrips biformis*. Thripidae, Thysanoptera

**Impact**

- infestations are more serious in the dry season.
- The pest infests the rice plant during the seedling stage or two weeks after early sowing

**Prevention**

- Use resistant varieties
- Flood to submerge the infested field for two days.
- Encourage biological control agents
- use of fungal insecticide (beauveria, metarhizium)

**Mole cricket** *Gryllotalpa orientalis.* Gryllotalpidae, Orthoptera

**Impact**

- The pest is polyphagous
- It feeds on the underground parts of almost all-upland crops
- cause heavy damage to roots and basal parts of rice plants growing in raised nursery beds or upland conditions

**Prevention**

- Use resistant varieties
- Flood rice fields for 3-4 days,
- Avoid construction of a raised nursery
- collect the nymphs and adults when preparing the land

**To control infestation**

- Encourage biological control agents:
- Poison insects by baits made by mixing moistened rice bran and insecticide and placing it along rice bunds or drier areas
- use fungal insecticide (beauveria, metarhizium)

**Rice armyworm**, *Mythimna separata* Lepidoptera, Noctuidae

**Impact**

- It is a problem at all stages of the rice crop
- High population numbers can totally damage the plants

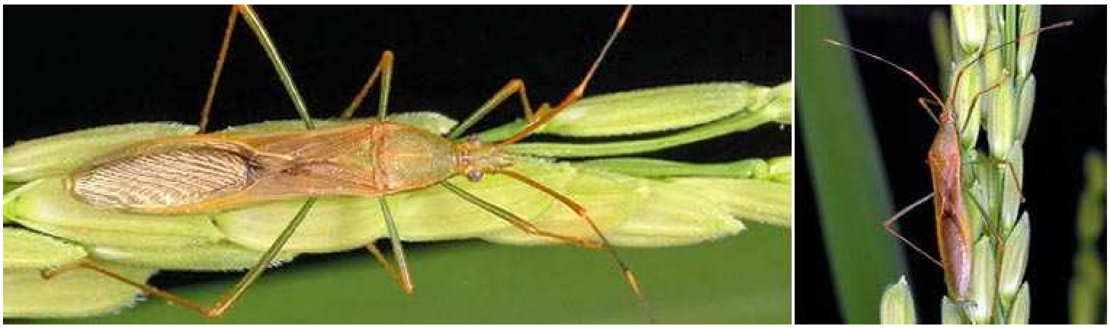
**Prevention**

- Establish seedbeds far from large areas of weeds
- Protect seedbeds
- Plow fallow land
- Clean the field and remove weeds.

**To control infestation**

- Place branches around fields to give armyworms a place to congregate where they are easily collected by hand
- Place ashes in the trenches to make it more difficult for the caterpillars to escape

- Use bacillus thuringiensis



**Rice bug** *Leptocorisa* sp Hemiptera, Alydidae

**Impact**

- Adults and nymphs feed on grains at the milking stage.
- Serious pests of rice with yields reduced up to 30%

**Prevention**

- Remove weeds from fields and surrounding areas to prevent the multiplication of pests
- Encourage rice to grow and develop is at the same rate.
- Capture rice bugs, in the early morning or late afternoon, by net
- biological control

**To control infestation**

- monitor the presence from flowering stage
- apply fungal insecticides

(Image source: Bayer crop science)[25]

**Rice water weevil**[26] - *Lissorhoptrus oryzophilus*, Curculionidae, Coleoptera

**Impact**

- active at seedling stage, vegetative growing stage
- Adults rasp the leaf epidermis of rice leaves,
- Root pruning by larvae causes stunting and chlorosis of seedling plants

**Prevention**

- Drainage of rice fields
- Delaying permanent flooding by 2 to 3 weeks affects larval population and reduces damage

**To control infestation**

- Use of bacillus thuringiensis proven to be successful.

---

[25]Source: https://www.cropscience.bayer.com/en/crop-compendium/pests-diseases-weeds/pests/lissorhoptrus-oryzophilus

[26]Source: https://www.cabi.org/isc/datasheet/30992#tosummaryOfInvasiveness

**Rice hispa** *Dicladispa armigera* Chrysomelidae: Hispinae

**Impact**

- The pest is a problem particularly in Bangladesh
- Can infest large areas and causes yield losses of up to 20%

**Prevention**

- Avoid over fertilizing the field
- greater leaf densities from higher densities that can tolerate higher hispa numbers

**To control infestation**

- Cut shoot tips
- Clipping and burying shoots in the mud can reduce grub populations by 75−92
- biological control with predators
- use of fungal insecticide (beauveria, metarhizium)

**Root aphid** *Tetraneura nigriabdominalis* Hemiptera: Aphidoidea

**Impact**

- The pest sucks the plant to remove fluids.
- The feeding damage causes yellowing of leaves and stunting
- infest during tillering stage

**Prevention**

- biological control agent

# Annex 4
## Diseases of rice[27]

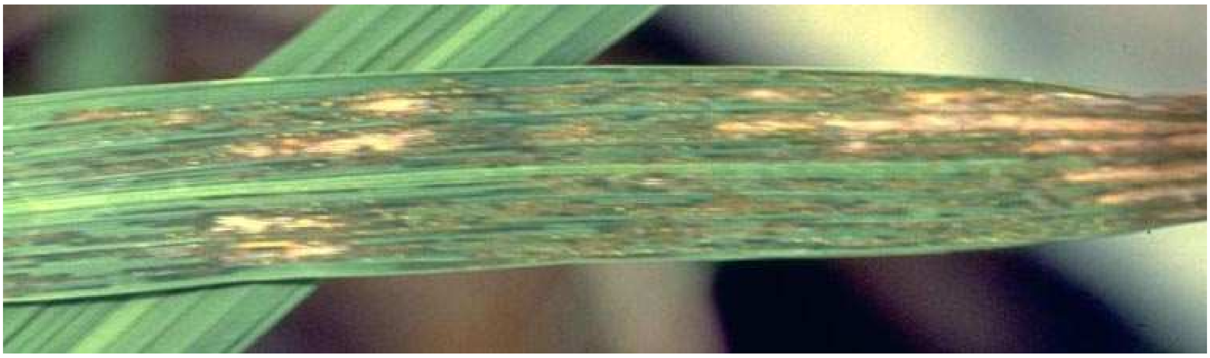
**Bacterial blight** - caused by the bacterium <u>*Xanthomonas oryzae*</u> pv. oryzae.

**Damages**
It causes wilting of seedlings and yellowing and drying of leaves.

**Why is it important**
Bacterial blight is one of the most serious diseases of rice. The earlier the disease occurs, the higher the yield loss. Losses are as much as 70% with susceptible varieties.

**How to manage**

- Planting resistant varieties
- Use good balance of nutrients without exceeding in nitrogen.
- Ensure good drainage of fields and nurseries.
- Keep fields clean from residues that can host of bacteria
- Allow fallow fields to dry in order to suppress disease



**Bacterial leaf streak** - caused by the bacterium *Xanthomonas oryzae* pv. oryzicola.

**Damages**
Infected plants show browning and drying of leaves. Severe attacks bring to reduced grain weight due to loss of photosynthesis.

**Why is it important**
Yield losses can be 8−17% in the wet season, and 1−3 % in the dry season.

**How to manage**

- Use resistant varieties.
- Treat seeds with hot water.
- Keep fields clean from residues, plow the residues into the soil.

---
[27] Source: Rice Knowledge Bank
http://www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/diseases

- Use balanced amounts of plant nutrients, do not exceed with nitrogen.
- Ensure good drainage of fields and nurseries.
- Dry the field during the fallow period to kill the bacteria in the soil and in plant residues.
- Chemical treatment:
  - In cases of severe infection, use copper-based fungicide applied at heading.

**Blast** (leaf and collar) - caused by the fungus *Magnaporthe oryzae.*

**Damages**

It can affect all above ground parts of a rice plant: leaf, collar, node, neck, parts of panicle, and sometimes leaf sheath.

**Why is it important**

Rice blast is one of the most destructive diseases of rice.

A leaf blast infection can kill seedlings or plants up to the tillering stage.

At later growth stages, a severe leaf blast infection reduces leaf area, grain fill and grain yields.

**How to manage**

- Use resistant varieties
- Adjust planting time. Sow seeds early, when possible, after the onset of the rainy season.
- Split nitrogen fertilizer application in two or more treatments as nitrogen enhance disease intensity.
- Flood the field as often as possible.
- Use Silicon fertilizers (e.g., calcium silicate) or use straws rich in silicon from rice varieties rich in silicon, but put care in ensure the straw is disease free.
- Chemical treatment:
  - Systemic fungicides like triazoles and strobilurins used judiciously.

**Brown spot** – caused by the fungus *Cochliobolus miyabeanus*

**Damages**

Brown spot is a fungal disease that infects the coleoptile, leaves, leaf sheath, panicle branches, glumes, and spikelets.

**Why is it important**
On average, the disease causes 5% yield loss. Severely infected fields can reach 45% yield loss. Heavily infected seeds cause seedling blight and lead to 10−58% seedling mortality. It also affects the quality and the number of grains per panicle, and reduces the kernel weight.
**How to manage**

- Improving soil fertility
- monitor soil nutrients regularly
- apply required fertilizers
- apply calcium silicate before planting
- Use resistant varieties.
- Treat seeds with hot water (53−54°C) for 10−12 minutes before planting, to control primary infection at the seedling stage. To increase effectiveness of treatment, pre-soak seeds in cold water for eight hours
- Chemical treatment:
    - use fungicides (e.g., iprodione, propiconazole, azoxystrobin, trifloxystrobin, and carbendazim) as seed treatments.

**False smut**

**Damages**
False smut causes chalkiness of grains which leads to reduction in grain weight. It also reduces seed germination.
**Why is it important**
The disease affects the early flowering stage of the rice crop when the ovary is destroyed.
The second stage of infection occurs when the spikelet nearly reaches maturity. These causes chalkiness
Reduction in seed germination of up to 35%. In damp weather, the disease can be severe and losses can reach 25%.
**How to manage**

- Keep the field clean.
- Remove infected seeds, panicles, and plant debris after harvest.
- Reduce humidity levels through alternate wetting and drying (AWD) rather than permanently flooding the fields.
- Use moderate rates of Nitrogen.
- Use certified seeds.
- Treat seeds at 52°C for 10 min.

Rice grassy stunt - virus

**Damages**

Reduced yields by inhibiting panicle production.

**Why is it important**

The virus occurrence is not widespread but can become serious when big infestations of brown planthopper occur.

**How to manage**

- Control brown planthopper vectors
- use of insecticides,
- brown plant hopper-resistant varieties,
- Synchronized crop establishment.
- Infected stubble needs to be ploughed under after harvest to reduce the virus source

**Rice ragged stunt** - Virus

**Damages**

Reduced yield from partially exerted panicles, unfilled grains and plant density loss.

**Why is it important**

The virus can affect up to 75% of plants in a crop. Infected crops will suffer significant yield losses of up to 80%.

**How to manage**

- Once infected by the virus, a rice plant cannot be cured.
- Use plant varieties resistant to brown planthopper.
- Use resistant varieties is probably the most important control measure.
- Synchronize planting.
- Plow infected stubbles in the soil after harvest to reduce the virus source.

**Sheath blight** - fungal disease caused by *Rhizoctonia solani*

**Damages**

Infected leaves senesce or dry out and die, young tillers can also be destroyed.
Leaf area is significantly reduced, which brings to low yields. Initial lesions above the soil or water level, initiated by sclerotia.

**Why is it important**

Serious disease next to rice blast. Depending on the regions the damage could account for 20-50%

**How to manage**

- There is currently no resistant rice variety available for cultivation.
- Use a reasonable level of fertilizer adapted to the cropping season.
- Use reasoned density of crop establishment (direct seeding or transplanting).
- carefully control of weeds
- drain rice fields relatively early in the cropping season to reduce sheath blight epidemics.
- use fungicide to treat seeds.
- provide wider plant spacing.

**Tungro** - combination of two viruses

**Damages**

Leaf discoloration, stunted growth, reduced tiller numbers and sterile or partly filled grains.
Tungro occur during all growth stages of the rice plant. It is most frequently seen during the vegetative phase. Plants are most vulnerable at tillering stage.

**How to manage**

- Once a rice plant is infected by tungro, it cannot be cured.
- Grow tungro or leafhopper resistant varieties.
- Practice synchronous planting with surrounding farms.
- Adjust planting times to when green leafhopper are not in season or abundant
- Plow infected stubbles immediately after harvest to reduce inoculum sources and destroy the eggs and breeding sites of green leaf hopper.

**Leaf Scald** - fungal disease caused by *Microdochium oryzae*,

**Damages**

Scalded appearance of leaves favored by wet weather, high nitrogen fertilization, and close spacing

**Why is it important**

Leaf scald causes considerable losses in Latin America and West Africa.

**How to manage**

- Use resistant varieties.
- Avoid high quantities of fertilizer. Split the applications of nitrogen.
- Remove weeds that can host infection.
- Plow under of rice stubbles.
- Remove infected rice ratoons.
- Chemical treatments:
    - benomyl, carbendazim, quitozene, and thiophanate-methyl to treat seeds.
    - In the field: spray benomyl, fentin acetate, edifenphos. Foliar application of captafol, mancozeb, and copper oxychloride also reduces the incidence and severity of the fungal disease.

**Narrow brown spot** - is caused by the fungus *Sphaerulina oryzina* (syn. *Cercospora janseana*, *Cercospora oryzae*)

**Damages**

Can infect leaves, sheaths, and panicles.

It leads to premature death of leaves and leaf sheaths, premature ripening of grains, and in severe cases, lodging of plants.

**Why is it important**

Severe damage caused by narrow brown spot decreases the market value of the grains and reduces the milling recovery.

**How to manage**

- Use resistant varieties.
- Remove weeds and weedy rice to remove alternate hosts
- Use balanced nutrients; make sure that adequate potassium is used.
- Chemical treatment:

- If diseases puts at risks the crops spray propiconazole at booting to heading stages.

**Red stripe**

**Damages**

Red stripe causes formation of lesions on leaves.
It is common in Indonesia, Malaysia, Philippines, Thailand and Vietnam.

**Why is it important**

Potential threat to rice production in Southeast Asia, but uncertain is the degree of losses

**How to manage**

- Use resistant varieties.
- Proper nitrogen management
- Keep optimum seeding rate and wider plant spacing to reduce the disease.
- Ensure intermittent drainage during panicle initiation.
- Chemical treatment:
    - use benzimidazole fungicides (benomyl, carbendazim, and thiophanate methyl) to treat seeds

**Bakanae** – seed-borne fungal disease.

**Damage**

The fungus infects plants through the roots or crowns. It then grows through the whole plant. Infected plants are abnormally tall with pale, thin leaves, produce fewer tillers, and produce only partially filled or empty grains.

**Why is it important**

Crop losses may reach up to 20% in outbreak cases.

**How to manage**

- Use clean seeds to minimize the occurrence of the disease
- Use salt water to separate lightweight, infected seeds during soaking
- Chemical treatment:

- Use fungicides as seed treatments - benomyl or benomyl-t (at 1-2% of seed weight) for dry seed coating to treat infested seed can be effective. Soaking seed in a fungicide solution of 1:1000 for one hour or 1:2000
- Avoid repeated applications of benomyl since the fungus can develop resistance to this treatment. In case of resistance use a fungicide that contains triflumizole, propiconazole, prochloraz or a combination of thiram + benomyl.

**Sheath rot**- fungal disease caused by *Sarocladium oryzae*.

**Damage**

Reduction of grain yields. Abortion of panicle emergence, production of unfilled seeds and sterile panicles. Reduction of the grain quality.

**Why is it important**

Sheath rot is most destructive when infection occurs during or after the booting stage, before the emergence of the panicle. It can cause 20−85% yield losses.

Infected seeds and mycelium carried by the rice crop residue play an important role as source of inoculum for primary infection.

**How to manage**

- Sheath rot is a seed-borne disease, use healthy seeds.
- Minimize insect infestation in rice field. Insects cause injuries to the plants that allow the fungi to enter the plant and cause infection.
- Remove infected stubbles after harvest.
- Use optimum plant spacing. Sow three plants per hill at 8" spacing.
- Apply potash at tillering stage.
- Apply foliar spray of calcium sulfate and zinc sulfate.
- Chemical treatment:
    - Apply a seed treatment fungicide like carbendazim, edifenphos, or mancozeb as seed treatment and foliar spraying at booting stage.
    - Apply a foliar fungicide like benomyl and copper oxychloride as foliar sprays.

**Stem rot** – fungal diseases

**Damage**

Formation of lesions and production of chalky grains and unfilled panicles.

The infection is seen on the rice crop during early heading and grain filling. The leaf sheaths decay and cause lodging and lower grain filling.
The infection bodies or sclerotia are found in the upper soil layer. They survive in air-dry soil, buried moist rice soil, buried straw, and in tap water. The sclerotia float on irrigation water and infect newly planted rice during land preparation.

**Why is it important**

It can cause heavy losses in many countries. In Vietnam, the Philippines, and India, losses from 30% to 80% were recorded.

**How to manage**

- Use resistant cultivars.
- Burn straw and stubble or any crop residue after harvest or let the straw decompose.
- Drain the field to reduce sclerotia floating and moving.
- Careful supply of fertilizer with split nitrogen in more rounds. Provide high potassium, Lime to increase soil pH.
- Chemical treatment:
    - fentin hydroxide sprayed at the mid-tillering stage, thiophanate-methyl sprayed at the time of disease initiation can reduce stem rot incidence in the rice field.
    - Other fungicides such as Ferimzone and validamycin A also show effectivity against the fungus.

**Bacterial Sheath Brown Rot** - caused by *Pseudomonas fuscovaginae*

**Damage**

It causes rotting in sheaths and grains of seedlings and mature plants.
The disease is seed borne

**Why is it important**

Not common disease, but yield losses as high as 72.2% in Indonesia. Under very severe infection, total yield loss (almost 100%) was observed in Madagascar.

**How to manage**

- Clean the field from crop residues and re-growth immediately after harvest, and off-season cultivation of a crop.
- Adjust sowing time to avoid low temperatures.
- Use clean seeds.
- Treat seeds with hot water at 65°C.

**Rice Stripe Virus Disease** - cause: virus

**Damage**

Can cause high yield losses when severe epidemics occur.

The virus is transmitted in a persistent manner by brown planthoppers.

**Why is it important**

Severe infection at the seedling to early tillering stage was reported to cause yield losses of 50–100%.

**How to manage**

- Grow resistant varieties.
- Adjust planting time so that the crop will be at the stem elongation stage or older before the insect come, as plants at the seedling to early tillering stages are highly susceptible to RSVD.
- Apply insecticides judiciously to reduce the population of planthoppers
- Practice synchronous planting over wide areas.
- Remove residues of the previous crop and weeds to reduce the presence of the virus and the population of the vector.

**Rice Yellow Mottle Virus** – cause: virus

**Damage**

RYMV comes from wild grass. The virus is transmitted by several species of beetles, grasshoppers.

RYMV can also be mechanically transmitted through inter-plant movement of sap

**Why it is important**

Important disease for Africa. Yield losses vary widely, from 10 to 100%. Early infection normally leads to higher losses.

**How to manage**

- Use of resistant varieties
- employ the use of large-scale synchronous planting combined with fallow period
- plow under infected crop residues immediately after harvest
- establish the crop before the increase in the vector population,
- burn infected plants, especially when infection is still low,
- regular weeding during the cropping season and even after harvest to reduce sources of inoculum.