VIETNAM SUSTAINABLE AGRICULTURE TRANSFORMATION (VnSAT)

INTERNATONAL RICE RESEARCH INSTITUTE (IRRI)

“1 MUST DO - 5 REDUCTIONS” - STANDARDS

Best Management Practices for Lowland Irrigated Rice in The Mekong Delta - Towards a Sustainable Future in Rice Farming

YEAR 2018

Preface

"1 Must Do, 5 Reductions" was certifided by the national department of Crop Production as a technical innovation (Decision No. 532 / QD-TT-CLT dated November 7, 2012). This is a package of farming practices developed from the "3 Reduction of 3 Gains" technique (No: 1579 QD / BNN-KHCN dated 30 June 2005) with the addition of ONE MUST (Must use certified seed) and the 2 REDUCTIONS (reductions in water use; and post-harvest losses.) The 1 Must Do, 5 Reductions (1M, 5R) is a package of advanced techniques for farmers to produce rice towards sustainable rice production standards and is a basis for establishment Small farmers, Large field (SF, LF), contributing to the stable and improved quality of rice for export. This opens up to rice growers a new direction; rice will be produced in a collective manner instead of individual, facilitating the synchronous application of advanced techniques for sustainable rice production and mechanization of production.

The 1M, 5R manual is updated in order to support the VnSAT project. The addition of new contents that focuses on (1) 1M, 5R standards required to set quality standards for the assessment the best management practices, including quantitative standards on seed rate, the use of fertilizers, pesticides, water, harvesting and storage; (2) the benefits of implementation alternate wetting and drying (AWD), to save water and also reduce methane gas emmissions; (3) mechanization and postharvest losses; (4) rice straw management options; and (5) management of stem borer, Rice Grassy Stunt Virus and Rice Ragged Stunt Virus. In addition, the manual content is arranged in sections relevent to farming practices so that readers can easily find desired information.

IRRI consultancy team updated the manual based on the manual 1M,5R under CoriGAP project in 2014. We hope that this manual will be a useful resource material for extension staff and rice growers.

Take this opportunity; we are grateful for feedback from staff in the Provincial Project Management Units of the VnSAT project who provided valuable comments. We thank colleagues at On Mon Rice Research Institute, Dr Ho Van Chien, former Director of Sounthern Regional Plant Protection Center (SRPPC), M. Le Quoc Cuong, Director of SRPPC and all colleagues for their assistance with providing photos and other aspects to finalize the booklet. We give a special thanks to the late Dr Nguyen Huu Huan, former General Deputy Director of Plant Protection Department for his great contribution to the origin and implementation of the 1M, 5R program in the Mekong Delta.

We would like to receive more feedback from readers to improve the quality of the booklet.

Editors:

Dr. Nguyen Thi My Phung

Dr. Nguyen Van Hung

Dr. Alex Stuart

Dr. Grant Singleton

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SECTION 1: THE CONTENT OF “1 MUST DO - 5 REDUCTION”

1. What is "1 must do 5 reductions"?

1.1. *“One Must Do"*

- ✓ Must use certified seed in accordance with current regulation
- ✓ Must grow rice varieties which are allowed to be produced and traded in Vietnam as recommended by the Agriculture Agency.

1.2. *"Five Reductions"*

- ❖ <u>Reduction in seed rate (the 1st reduction)</u>

The appropriate amount of seeds sown will optimize rice productivity. A high seed rate will cost more for seeds and fertilizer, and may cause negative effects on crop stand and rice lodging that may contribute to increase cost production and decreased rice yield. A dense canopy resulting from a high seed rate can lead to increased risk of pests and diseases.

The main measures to reduce seed rate

- ✓ Certified seeds must be used;
- ✓ A seed rate of 80-100kg/ha should be used;
- ✓ Level the land well before sowing;
- ✓ Manage water carefully after sowing;
- ✓ Apply golden apple snail management where needed;
- ✓ Use row seeder/ transplanting;
- ❖ <u>Reduction in excess N fertilizer (the 2nd reduction)</u>

Balanced fertilization will help avoid loss of fertilizer to streams, rivers and air, and help rice plants grow more vigorously and reduce favourable conditions for pests and diseases. An increase in the fertilizer use efficiency is most likely to contribute to reductions in production cost and optimise rice productivity. If nitrogen is overused, rice plants are likely to be more susceptible to insect pest damage, disease incidence and lodging.

The main measures to reduce overused N fertilizer

- ✓ Use seed rate/planting density of 80-100kg/ha;
- ✓ Apply balanced amount of fertilzers, 110kg N/ha is maximum amount to be used (Fertilizer amount and application time are shown in detail in Section 2).

- Reduction in pesticide use (the 3rd reduction)

Rational use of pesticides will help reduce production costs, improve the health of rice growers, limit environmental pollution and conserve natural enemies of pests. A general principle is ‘encourage the early appearance of natural enemies in the rice ecosystem to maintain pest populations under their economic threshold’.

The main measures to reduce pesticide use

- ✓ Use 80-100kg seeds/ha;
- ✓ Sow synchronously following recommended by local agricultural agencies;
- ✓ Apply balanced amount of fertilzers, 110kg N/ha is maximum amount should be applied;
- ✓ No early insecticide sprays during first 40 days after sowing (DAS);
- ✓ Only apply pesticides if necessary. The use of pesticides should follow “4-right principle” promoted by agricultural agencies.
- ✓ Ecological engineering technique should be practiced (planting nectar-rich flower plants on the bunds surrounding rice fields) to enhance biodiversity that will attracts many natural enemies as parasitoids and predators.

- Reduction in water use (the 4nd reduction)

The principle is that rice plants do not always have to be grown under flooded conditions. Good water management will help rice root system develop well and absorb more nutrients. This make the rice plants less prone to lodge, optimize rice productivity, and reduce pumping/irrigation costs.

The main measures to save water

- ✓ Land should be well levelled;
- ✓ Farmers are able to actively take control for irrigation/drainage of their crop;
- ✓ Implement ‘Alternate wetting and drying’ technique.

- Reduction in post-harvest losses (the 5th reduction)

Post harvest losses are affected by various operations of land preparation, pre and post harvest.

The main measures need to conduct synchronously *to reduce post-harvest losses*

- ✓ Land should be well levelled (ex. Implement laser levelling),
- ✓ Implement mechnical transplanting,
- ✓ Select varieties that are less prone to lodging,

- ✓ Apply right fertilizer quanlity & it should be spread uniformly in the fields,
- ✓ Apply Alternatively Wetting and Drying,
- ✓ Apply best management practices based on 3G, 3R, or 1M, 5R;
- ✓ The rice crop should be harvested when 85-90% of the grains have the color of straw. The use of a combined harvester is recommended to minimize postharvest losses and to reduce harvesting cost,
- ✓ Best practice is to dry wed paddy within 24 hours after harvesting,
- ✓ The drying temperature, with flatbed dryers widely used in MRD should not be exceeded 40°C for seeds and 43°C for commercial rice,
- ✓ The safe moisture content of paddy for storage is not higher than 14% for commercial rice grains and ≤12% for seed;
- ✓ Grains should be cleaned prior to storage. This contributes to limitting insect and fungi and also improving head rice yield.
- ✓ Well manage insects, rat infestation during storage.

2. The requirements for application "1 must do 5 reductions"

- ✓ Enough certified seeds;
- ✓ The land needs to be well leveled;
- ✓ Farmers can actively take control for irrigation/drainage of their fields;
- ✓ For economic use of agricultural machinery, the field size should be large enough (≥ 1ha).

3. The benefits of application '1 must do 5 reductions'

- ✓ Reduction in costs of production;
- ✓ Do not change in productivity; more resilient to extreme climate events (= "Climate Smart" practices)
- ✓ Improved rice quality;
- ✓ Reduce postharvest losses
- ✓ Increase in the rice growers' profit;
- ✓ Save water resource;
- ✓ Reduction in greenhouse Gass (GHG) emissions.
- ✓ Contribute to the improvement of community health through reduced use of chemicals;

- ✓ Limit environmental pollution and therefore increase conservation of biodiversity

SECTION 2: "1 MUST DO AND 5 REDUCTIONS" PROCESS OF PRODUCING RICE AND THE STANDARDS

1. "1 Must Do, 5 Reductions" process for rice cultivation

To reduce the production costs but improve rice quality and productivity, it is necessary to apply integrated measures from land preparation, sowing, etc. to harvest, and storage.

1.1 Planting season

Planting season is very important. Sowing at proper seasonal calendar will help the rice crop:

- Grow well and produce high yield;
- In being less affected by damage caused by adverse weather including extreme temperatures (too hot, too cold), drought, storm, floods;
- Avoid being damaged by some rice pests as thrips (*Baliothrips biformis*), whitefly (*Aleurocybotus* sp.), panicle rice mite (*Steneotarsonemus spinki* Smiley, 1967), red stripe (*Gonatophragmium sp*. Deighton), etc.

Accordingly, rice establishing should follow recommendation by the local Agriculture Agency

1.2 Land preparation

Good land preparation is one of the crucial factors affecting the paddy yield in lowland rice production system. Land preparation should have a cultivation layer of about 20-30 cm. Also the soil, particularly where 3 rice crops per year are grown, should be allowed to dry thoroughly at least 2-3 weeks between the rice seasons to facilitate seeds to initially grow well. This is the premise of stabilizing and increasing crop yields.

Well-prepared land will have the following benefits:

- Destroy diseases associated with a previous infected crop;
- Quickly decompose stubble that supply nutrient to rice crop and avoid the negative effects of organic acids;
- Reduce seed rate;
- Soil can keep moisture well that facilitates good germination and effective herbicide usage;
- More effective weed and Golden apple snail control;

- Soil is of porosity that will help the rice crop grow well, increase yield, reduce lodging and postharvest losses;
- Facilitate implementation of water saving using Alternate Wetting and Drying;
- Reduce in irrigation cost;
- Reduce in input cost;
- The nutrition to be distributed evenly in the field so the rice crop can grow uniformly. This increases the chance of obtaining high yields and head rice recovery after being processed;

In addition to good land preparation and leveling of the field, it is necessary to construct small canels in the field for irrigation and drainage.

1.3 Seed selection

Good quality seed is the prerequisite of high productivity.

The certified seed must meet seed quality standards, according to Vietnam standards of rice seed quality QCVN 01–54: 2011/BNNPTNT which was issued in 2011 by Ministry of Agricuture and Rural development, at Circular No. 45/2011/TT- BNNPTNT June 24, 2011:

- ✓ Rice seed should be bright, few or no grain discoloration, empty grain seed, or abnormal seeds.
- ✓ Seed should be pure and no impurity with other varieties or weeds or weedy rice seeds; there should be more than 80% germination.
- ✓ Seed should be free of pests, fungi or diseases.

1.4 Seed rate

Seeding density: refers to the number of germinated seeds or the weight of the seeds per unit area (kg ha^{-1}). The appropriate number of seeds sown per hectare will ensure a maximum rice yield and create favorable conditions for the activity of natural enemies. This is also a measure at limiting the development of rice pests and reducing pesticides costs.

- Seed rate: The suitable seed rate for sowing ranges from 80-100 kg/ha. For transplanting, the seed rate reduces to 60kg/ha.

- For example, the seed rate of only 60 kg/ha sown under optimum conditions of good weather, fertile soil, no pest damage, etc. will produce 240 plants/m^2 (25 g/1000 seeds) x 2-3 tillers per hill = 480-720 panicles/m^2. About 500-600 panicles/m^2 is required for an optimum yield.

The seed rate can be adjusted depending on varieties, seasons, soil fertility, and weather conditions.

Avoid sowing with high seed rate as it will cause the following disadvantages:

- Increase in cost for seeds;
- Increase in cost for fertilizers and pesticides;
- Low rice quality and productivity;
- High production cost, low profit.

1.5 Crop care

1.5.1 Weed management

There are three main groups of weeds in rice fields: grass weeds, broadleaf weeds, sedge weeds. If weedy rice is a major threat in rice fields, one should consider rotating with other crops, at least once per year.

Weeds should be controlled early using pre-germination herbicides to avoid competition between rice plants and weeds. That facilitates the rice crop to well establish at the early stage. If there are weeds still left in the field, hand weeding or post-germination herbicides should be implemented prior to the 2nd fertilizer application.

In order to achieve better weed management, the following measures should be implemented:

- ✓ Certified seed should be used;
- ✓ Land should be well prepared (ex. well land levelled…);
- ✓ Row seeding or mechanical transplanting should be implemented;
- ✓ Water the rice field at the early stage to restrain weeds' germination.
- ✓ Weeding should be carried out in combination with re-planting during the rice growth stage from 15 to18 DAS;
- ✓ Weed's panicles left in the rice fields need to be removed in order to prevent weeds from forming seeds which are a source of infection for future seasons;
- ✓ Weeds in banks and irrigation canals in the rice field should be well managed.
- ✓ Types of herbicides should be alternatively applied complying with the four "right principles" which are as followed:

* **Right type:** kinds of weeds and grasses which have been regularly observed in the rice field should be recognized. This helps to choose the appropriate herbicides;

* **Right dose and concentration:** dose and water volume shown on labels or

packages need to be followed.

* **Right time:** according to irrigation service in the compartment area to choose suitable herbicides.

* **Right spraying method**:

- Depending on impacts of herbicide (systemic via roots, stems, leaves, or flora exposure), a suitable way of spraying will be chosen in order to ensure herbicide solution be spread all over the field surface;
- Soil moisture content should be maintained during and after spraying as it plays an important role in optimizing herbicide functions;
- Herbicides should not be applied during high temperatures, windy conditions or if it is going to rain;
- Flat conical nozzle is suitable for spraying herbicides in rice fields;
- Calibrate sprayer before spraying.

1.5.2 Water management implementing Alternatively Wetting and Drying (AWD)

General principle**:** *paddy crops do not always require continuous flooding except for the seedling stage to suppress weeds and the flowering stage to form grains*. **"Alternate wetting and drying"** (AWD) can be applied during the other rice growth stages.AWD was invented and promoted by IRRI scientists (Bouman et al., 2007). **Wetting** refers to water level at 3-5 cm height from soil surface; **drying** refers to water level at 15 cm under the soil surface (See "How to apply AWD" at Part 3).

AWD significantly provides the following benefits:

- Minimizes inactive tillers. The active tillers can be grown better due to more nutrition;
- Minimizes shading, less dead and yellow wilted leaves at the base of rice culm, and less damage caused by rice pests;
- Roots can grow deeper and get more nutrition to support the rice plant;
- Less lodging due to better root anchorage;
- Save pumping cost for irrigation; and
- Reduce emission of greenhouse gases, as:
  - ✓ A single aeration of the field, commonly referred to as 'midseason drainage', reduces CH_4 emissions by 40%, as the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines suggest.

- ✓ ‘Multiple aeration’, the category AWD is presumed to reduce CH_4 emissions by 48% compared to continuous flooding of rice fields (IPCC, 2006).

According to a study on CH4 emissions in four different agro-ecosytems, namely alluvial soils, salinity intrusion, deep flood, and acid sulfate soils in the Mekong Delta by Vo, et al., 2017, emission factors from rice vary strongly between the different agro-ecosystems from 1.14 kg CH4/ha/day in saline soils to 9.14 kg CH4/ha/day in deep flood areas. The average emission factor across the Mekong Delta is 1.92 kg CH4/ha/day.

1.5.3 Fertilizer application

1.5.3.1 The principle of fertilizing

Only apply for plant needs at the main rice growth stages (the seedling, tillering and panicle initiation stages) with right amount, especially avoid overusing Nitrogen (N). The recommended amount of fertilizer for 85-100 day - variety in three different ecological zones is shown in table 1 (Decision No. 532 / QD-TT-CLT dated 7th November 2012 for referrence). An extra 20% of total nitrogen can be applied for the varieties with growing time of more than 100 days and the area cultivated for 3 crops per year for many years without depleting soil N. Also, compost is recommended to be used to improve soil fertility. The same fertilizer quantity is applied for Summer-autumn and Winter-spring seasons.

1.5.3.2 Application time and the amount of fertilizer used

The amount of fertilizers and application times can be changed appropriately depending on growing condition, cropping season, rice growth stage of variety being currently grown and the types of fertilizers.

Table 1: Amount of fertilizer N-P-K recommended for different types of soil and cropping seasons for 85-100 day duration rice varieties (Mekong Delta Rice Research Institute)

Types of soil	**Amount of N-P-K fertilizer (kg ha^{-1})**					
	Nitrogen (N)		Phosphate (P_2O_5)		Kali (K_2O)	
	WS	SA	WS	SA	WS	SA
Alluvium	90 - 100	75 - 90	30 - 40	30 - 40	30 - 40	25 - 30
Light acid sulphate	80 - 100	70 - 80	40 -50	40 - 50	25 - 30	25 - 30
Moderately acid sulphate	60 - 80	60 - 65	50 - 60	50 - 60	25 - 30	25 - 30

Note: Winter-spring (WS), Summer-autumn (SA), Winter-spring(AW) seasons.

+ **Basal:** Depending on acidity levels in acid sulphate soil, the amount of Phosphate could be adjusted from 200 – 500 kg/ha during land preparation to low soil acidity and help root system establish well.

+ **Top dressing**: 3 main fertilizer applications as shown in **Table 2**

Table 2: Top dressings associated with rice growth stages

Top dressing	N	P_2O_5 (DAP)	K_2O
1st .7-10 DAS	30%	50%	50%
2nd. 18-22 DAS	40%	50%	
3rd. at panice initiation	30%		50%

The suitable time for the 3rd fertilizer application: Fertilization should be based on the rice growth stages and appearance of primordium. For example, fertilizers should be applied during 35-40 DAS for 90-day duration varieties (20 to 25 days prior to the flowering stage). Also priomordium is checked by pulling up 10 rice tillers in two diagonal lines in the rice field. If primordium 1-1.5 mm long is observed in 7-8 tillers out of 10 tillers that is suitable time for fertilization (or when effective tillers that can be observed from the bank get rounder it'ss time for the 3rd fertilize application.)

The efficiency of fertilizing at the suitable time: this is a critical stage during the rice plant development because it has very short time to shift to panicle differentiation stage to form rice panicles, spikelets. Therefore, fertizers application needs to be conducted at the right time in order to achieve the optimal numbers of spikelets and panicle branches for high yield.

* Note:

- Re transplanting should be conducted prior to the 2nd fertilizer application in order for the rice crop to grow uniformly.

- All of P_2O_5 should be applied at the 1st top dressing if a single P fertilizer is used.

- If the other NPK fertilizers are applied, the amount of fertilizer should be calculated based on the recommendation above or follow recommendations of local agricultural agencies.

1.5.4 Integrated Pest Management (IPM) and Promoting Biodiversity

❖ **IPM principles**

To minimize the negative human health and environmental consequences from pesticide use and to safeguard the rice growing environment for future generations of rice farmers, it is important that IPM principles are adopted. According to the Sustainable Rice Plaform Standard, the principles according to IPM include:

- *evaluating pest and damage levels regularly (scouting)*

- *evaluating all available pest control options*

- *using action thresholds recommended by local government extension experts*

- *selecting a crop protection method that maximizes human safety, minimizes environmental impact, is economically justifiable, and prevents food safety risks for all crops.*

IPM combines non-chemical control methods and rational pesticide use. This includes biodiversity-based integrated pest management as part of crop protection activities.

Chemical control is only one approach among several available for pest management. Therefore, it is necessary to understand the ecological characteristics of a pest, factors favoring pest population development and symptoms caused by them, in order to implement timely management practices. For pests to be managed effectively, integrated approaches consisting of cultural, physical, mechanical, biological, and chemical practices are recommended. The aim is to maintain pest populations below a threshold that can cause economic injury. The following are recommended practices.

✓ The 3G, 3R or 1M, 5R should be practiced to facilitate rice crop development after sowing. This would help the rice crop resist adverse environmental conditions and pest damage;

- ✓ Sanitation, ploughing buried infected rice straw, ratoons and especially weeds that are alternative hosts and source of infection for the next rice cropping season right after harvest;
- ✓ Rice crops should not be grown continuously throughout the year. Fields are recommended to fallow for at least 2 weeks between crop cycles;
- ✓ Resistant varieties should be used where appropriate;
- ✓ Synchronize sowing/planting of crops in compartment area within 2 weeks, following local agricultural agencies' recommendation;
- ✓ Use an approriate seed rate/plant density of 80-100 kg/ha;
- ✓ Good management of weeds;
- ✓ Use balanced fertilizer, avoid N fertilizer overuse (maximum is 110kgN/ha);
- ✓ No need to use insecticides before 40DAS because the rice crop can compensate for damage caused by leaf-eating insects and also no insecticide use will help maintain natural enemies in the rice fields;
- ✓ Regularly visit rice fields to detect early symptoms/damages and monitor pest populations;
- ✓ If chemicals are used it is necessary to comply with the 4-right principles;
- ✓ Ecological engineering technique should be practiced.

❖ **Promoting Biodiversity – focus on natural enemies**

Rice fields support an array of life, both fauna and flora, all of which are important for a healthy rice ecosystem. The rich fauna and flora of rice ecosystems contribute to ecosystem functioning and stability, providing a wide variety of ecosystem services such as pest control, organic matter decomposition/nutrient recycling and food provisioning via wildlife harvesting. The high diversity of arthropods found in irrigated rice ecosystems form the basis for pest regulation. Natural enemies of arthropod pests in rice fields include arthropod predators and parasitoids, insectivorous birds, amphibians and bats. Overuse of pesticides can reduce the natural enemies' populations, while inducing development of pesticide resistance among the pest populations. Pest resurgence and secondary pest outbreak in rice ecosystems usually occur due to the removal of natural enemies after pesticide use. Ecological engineering, e.g. flower or vegetable strips next to rice fields, can be used for biological pest control by providing food and shelter for natural pest enemies, such as parasitoids and predators.

1.5.5 Postharvest

In order to minimize post-harvest losses, proper techniques should be applied in the stages from harvesting to milling (see section 1, at 1.2. Reduction in post-harvest losses (the 5th reduction). More details of harvest and post harvest are shown in Section 4.

2. The VnSAT standards for 1M5R

(Revised following the workshop on "water management, post harvest loss and SRP standards" in May 15-17, 2018 in An Giang with the attendance of CPMU, 8 PPMUs, farmer organizations and rice exporter companies).

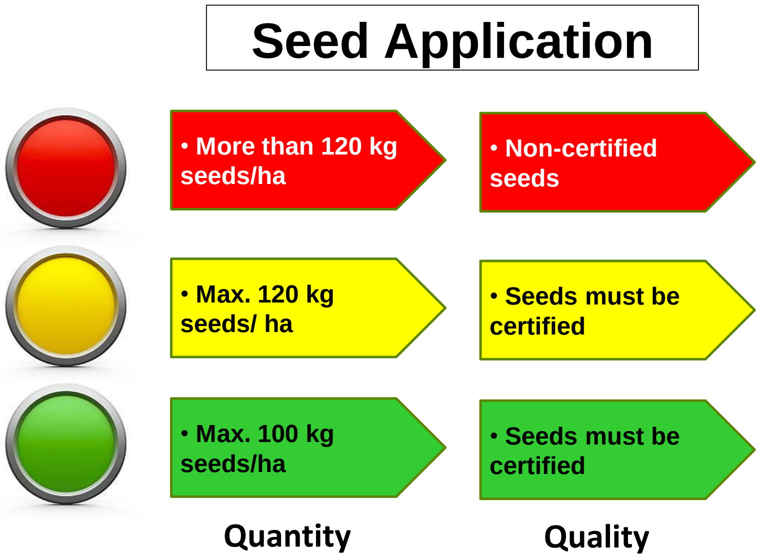
The standards are:

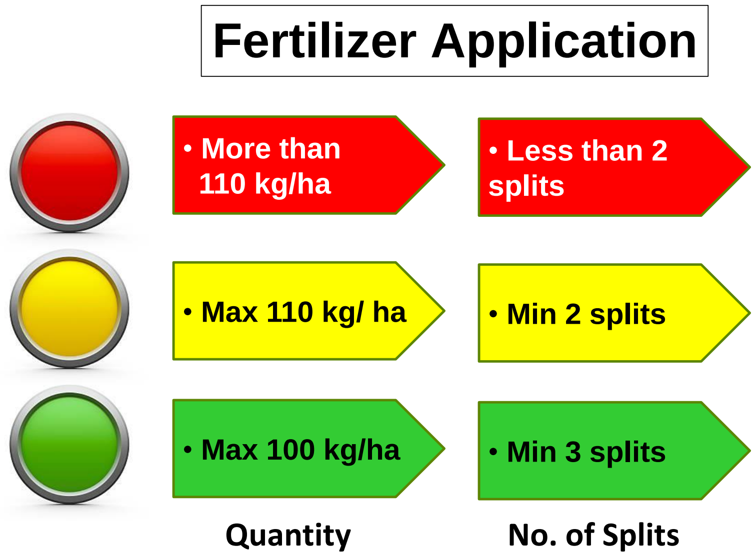
• updated based on actual conditions and towards high quality markets (Sustainable Rice Platform standards, GAPs, etc.)

• measurable / quantifiable,

• Farmers' Organizations can apply them readily,

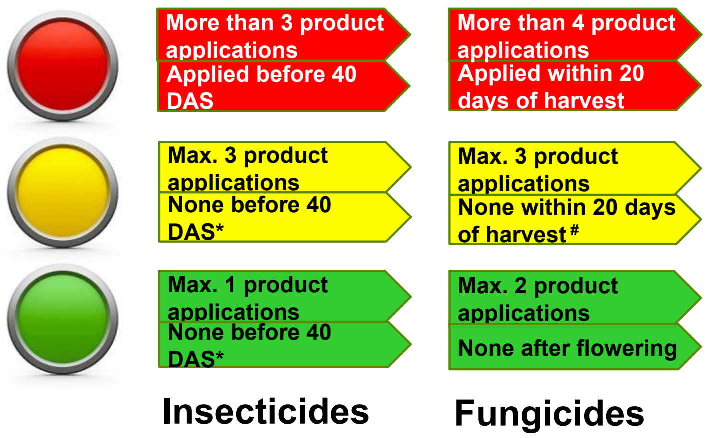
Summary of recommended standards for best management practices under 1Must Do, 5 reductions. Green is best practice, Yellow is acceptable as on pathway to best practice, Red indicates best practice is not met.





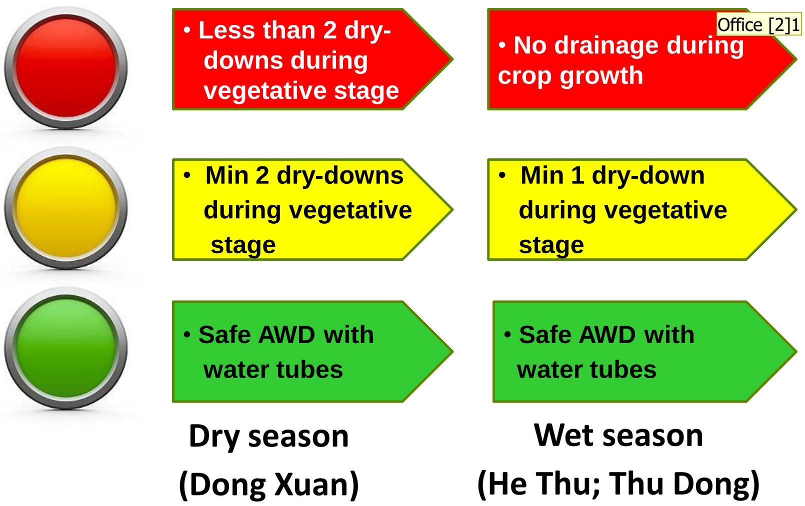
- Within these criteria, a specific guidelines following season and ecosystem as indicated in Section 2 of the manual.

Pesticide Application



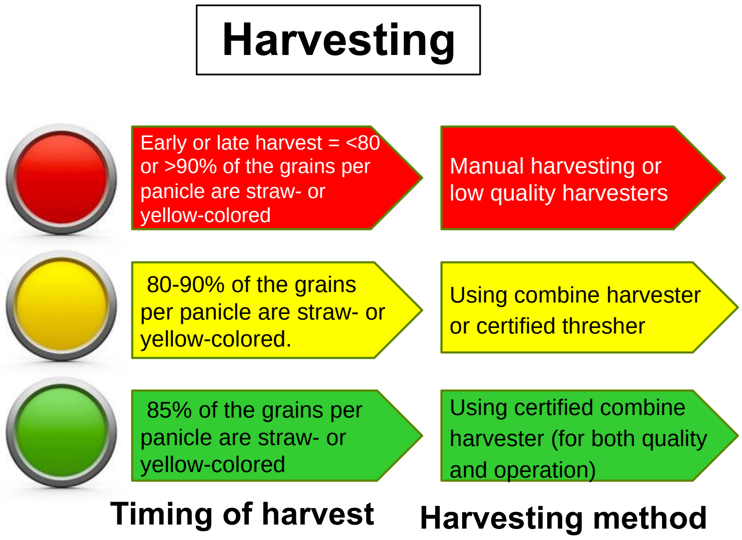
- Farmers must meet criteria in both columns
- Score individual **product** applications, e.g. 2 different products applied in one spray counts as 2 applications (1 product may include 2 active ingredients)
- *Exemption = insecticides can be applied <40DAS if following IPM recommendations by local extension experts
- #Fungicides should not be applied more than 10 days after flowering

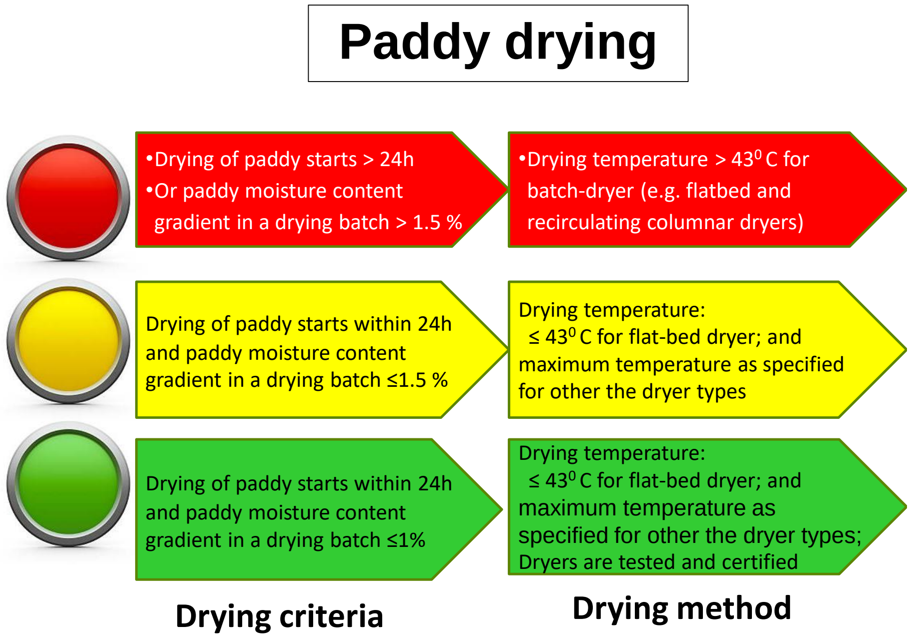
Water Application



*Each dry-down should be minimum 5 days

- Each dry downs should be for minimum of 5 days, but in the wet season, a shorter drainage period is acceptable if heavy rainfall occurs
- Fields should be flooded 1 week before and 1 week after flowering





Paddy storage

(applicable for the FOs having storage warehouse/ facilities)

	Storage criteria	Storage method
Red	> 14% moisture content for storing grain more than 1 week	Fumigation storage
Yellow	≤14% moisture content for storing grain. ≤12% moisture content for storing seeds	≤3 months for warehouse storage with bag or bulk
Green	•≤14% moisture content for storing grain. •≤12% moisture content for storing seeds	Do not use fumigation-storage (hermetic and aeration storage are encourage)

Straw management

	Criteria	Solution and technology
Red	Burning straw in the field	Manual operation
Yellow	•No burning straw in the field	•Incorporating straw with pre-treatment supports (inoculants, chopping) and for rice cropping ≤ 2 seasons/year •Collecting and Using straw for sustainable uses
Green	•No burning straw in the field •Following the standards of safe production (e.g. for mushroom, fodder, and compost)	•Using balers for collection •Collect straw for sustainable uses e.g. mushroom, ruminant fodder, bioenergy, and compost

SECTION 3: METHODS FOR RICE PRODUCTION UNDER "1 MUST DO AND 5 REDUCTIONS'

1. Seed treatment

Seed treatment is one of the recommended practices of integrated pest management (IPM). Seed testing and seed treatment ensure a high germination level and vigorous seedlings.

- ✓ Check moisture content of rice seeds: these seeds should be dried under the sunlight once or twice from 8 am to 12 pm in the morning to enhance their absorbence and germination;
- ✓ Test for germination ability: take a handful of seeds for soaking and incubating. The germination rate should be more than 80%;
- ✓ Seed dormancy treatment: for newly harvested grain seeds, dormancy is treated using acid Nitric 5‰ that can be trialed to select an appropriate concentration from 2-10‰;
- ✓ Seed treatment using the solution of NaCl 15%: put seeds in the solution of NaCl 15% (by mixing 15 kg of salt with 100 liters of water), hand stir and leave for 15 minutes. Remove the grain seeds that are empty or damaged by pests and weeds that are floating in the water. Good seeds, which are on the bottom, will be used for soaking and incubating normally for sowing. This practice is very useful to remove unfulfilled grains, weed seeds, seed-borned diseases.
- ✓ Seeds can be treated by soaking in the solution of lime 3% (200-300 grams of dissolved lime in 10 liters of water) for about 10-12 hours. This can prevent and control seed-born diseases.

2. Alternate wetting and drying (AWD)

This technique is implemented at the main rice growth stages, starting after the 2nd fertilizing onward.

From sowing to the 2nd fertilization: water is managed in normal way

+ <u>After sowing:</u> the water needs to be drained out of the field which is just moist enough to avoid germinated seeds dieing from being flooded

+ From <u>7-10 DAS</u>: water the rice field at 1-3 cm depth for the first fertilizer application (<u>7-10 DAS</u>). Applying fertilizer in saturated soil, followed immediately by irrigation to 1-3 cm of water will also help to increase snail mortality. This water level should be maintained up to the second fertilizer application (18-22 DAS). Maintaining water at this stage will favor suppression of weeds, but avoid raising the water level higher than 3 cm during this stage to minimize snail damage.

From after the 2nd fertilization to before the flowering stage: only re-flood the field up to 5 cm when the water level drops to 15 cm depth below the soil surfaceError! Reference source not found.)

Allowing the water level to drop as much as possible to 15 cm depth below the soil surface before irrigation will help to reduce development of ineffective tillers and promote roots to grow deeper, leading to less lodging. Although water cannot be seen on the soil surface at the threshold of 15 cm depth, water is still available at the root area and is sufficient for rice growth. Also, because rice canopy is developing and quite full (or closed) during this stage, germinating weeds are unable to compete with rice plants due to lack of sunlight.

Note: Fields should be watered to 1-3 cm for the 3rd fertilizer application to reduce fertilizer loss, especially, N fertilizer through evaporation.

Figure 3: Re-flood the rice field to 5 cm depth after water has dropped to 15 cm below the soil surface for the period from 22 DAS until before the flowering stage (Source: from poster @ IRRI, 2004: Distributed by IRRI, NIA and PhilRice).

From 7 days before flowering to 7 days after flowering: the field should be kept flooded at maximum 5 cm during 2 weeks, a week before and a week after the flowering stage (Error! Reference source not found.). The rice plants will be most sensitive to stresses such as low and high temperature and drought during this rice growth stage. Therefore, lack of water at this stage will cause sterility, reduction in numbers of spikelets per panicle and affect considerably maturing process. However, it is not necessary to keep flooded at this stage. Soil can be kept at saturated moisture.

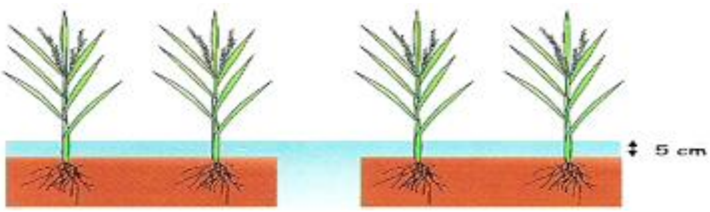


Figure 4: Water should be always kept at 5c m depth for 2 weeks

(1 week before and 1 week after the flowering stage)

After the 2-week flooding period: the water level can be allowed to drop again to 15 cm below the surface before re irrigation at maximum 5 cm.

Prior to harvest: water should be drained before harvest time from 5-7 days (for rice fields which land height higher than that of normal fields. Water can be drained more quickly than the normal fields) and 10-15 days (lower fields) to speed up rice maturity and facilitate machine activity for harvesting.

*** The way to monitor** water level in rice field: the level of water can be monitored using water tubes (15 cm in diameter and 30 cm long), holes (in 0.5-1.0 cm diameter and 5 cm apart from one another). The tube will be placed vertically into the soil but should be left 10 cm above the soil surface. Note that soil inside the tube needs to be removed down to the bottom of the tube. Water will flow through the holes into the tube so the water level inside the tuble is the same as outside (**Figure 5**).

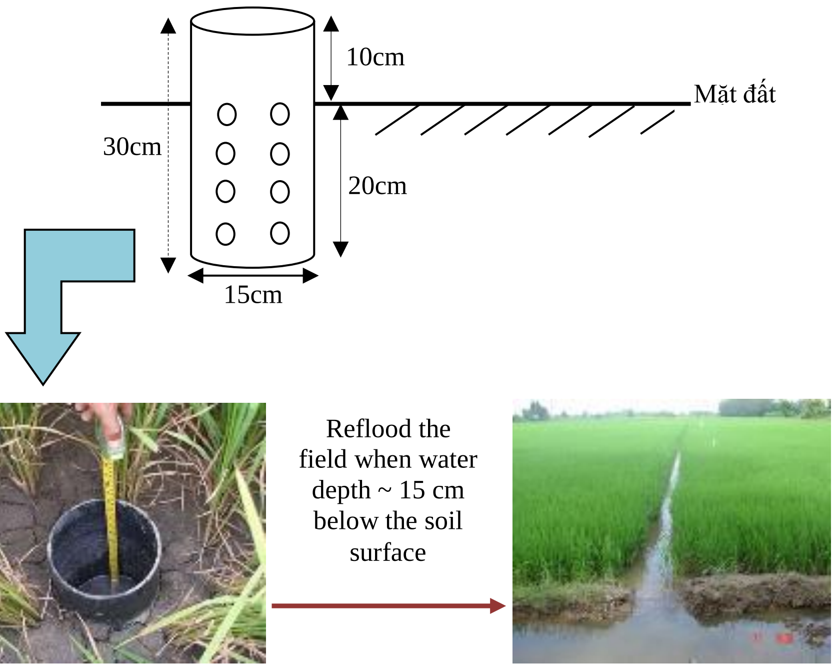


Figure 5: Appearance of water tube and the way to install it in rice field

3. Some major rice pests

In addition to the integrated management measures described in the Integrated Pest Management (IPM) section, more appropriate management measures will be required depending on the kind of pests to achieve high effeciency.

3.1. Golden apple snail (*Pomacea canalicuta & Pomacea maculata*)

Golden apple snail (GAS) causes damage to rice plant by feeding on seedlings from sowing to 30 DAS or newly transplanted rice crops. Due to exposure of younger plants to GAS, direct seeded rice crops are more susceptible tosnail damage than transplanted crops. When the rice plants are too old for GAS to eat, they feed on germinating weeds instead. Females lay egg masses on objects above the water surface. Their eggs are fresh pink (Error! Reference source not found.). There are about 150-300 eggs /egg mass and 500-1000 eggs are laid on average per month. The eggs take 7 – 28 days to hatch, with hatchability of about 90-95%. GAS mainly live in aquatic environments such as ponds, swamps, irrigated fields, and canals. However, they can aestivate for 6 months during the dry season by burying themselves deep in moist soil within 10cm of the soil surface. Then become active again when the soil is flooded. They can damage rice throughout the day but are most active at dusk and dawn, and during the night. GAS may also bury themselves during the day to escape the heat.

Factors favoring GAS development

- Presence of alternate hosts as duckweed, water hyacinth, and other succulent leafy plants;
- Overuse of N fertilizer which promotes growth of algae (a food for GAS)
- Continuously flooded rice fields

Figure 6: GAS is feeding on seedlings and bright pink egg sclutches attached on rice plants

GAS management:

- To achieve high snail mortality use a fast rotary cultivation and till the field intensively to crush snails hiding in the mud.
- Conduct snail and egg collection early in the morning during land preparation and crop establishment. Destroy snails by crushing or by cooking and feeding to fish/livestock. Destroy eggs by crushing or submerging in water.

- Snail collection can be improved by creating small canals or ditches in the field and by using plant attractants, e.g. papaya leaf, cassava leaf.
- Egg collection can be improved by placing bamboo sticks in flooded paddies.
- Install screens with 5 mm mesh at water inlets. This can minimize the entry of snails into the rice fields and will also facilitate hand-collection;
- Herding ducks in fields before sowing or after harvest is also recommended as biological control;
- Nitrogen fertiliser is harmful to the apple snail when applied in 1-3 cm of water (especially if applied in saturated soil immediately followed by irrigation). Applying N at basal stage will maximize snail mortality before sowing and to give seedlings a growth boost to reduce damage during the vulnerable stage.
- Limit to one molluscicide application if needed and for rice < 30 days old. Should only be used immediately after transplanting and no later than the seedling stage in direct seeded rice.
- Metaldehyde is significantly less toxic to fish than niclosamide. Niclomaside can also have a negative affect on rice seedling emergence.
- Keep fields drained as much as possible (keep water below 2 cm) during the vulnerable stages of the rice plant (before rice is 30 days old).
- Transplanted rice is less vulnerable than direct seeded rice.
- Longer dry fallow periods or a dry crop (e.g. soya, maize) between rice crops will also reduce snail survival.

3.2. Rice field rats

Rats can cause damage to rice crop at any rice growth stages but the highest damage at the panicle initiation stage. Significant annual pre-harvest losses are caused by rats to lowland irrigated rice and these have been recorded at 5-10% in Vietnam. The damage can be up to 30% in rice fields in some years when rodent numbers are high. If damage is <10% then rice crops can compensate for damage occuring during the early rice growth stages by re-tillering.

The rice field rat *Rattus argentiventer* (Error! Reference source not found.**A**) is the dominant species in rice cropping systems in Vietnam. They damage the rice crop by cutting or pulling up transplanted plants resulting in missed hills (Error! Reference source not found.**B**), or cutting stems, usually at 45^o to chew ripening rice grains (Error! Reference source not found.**C**).

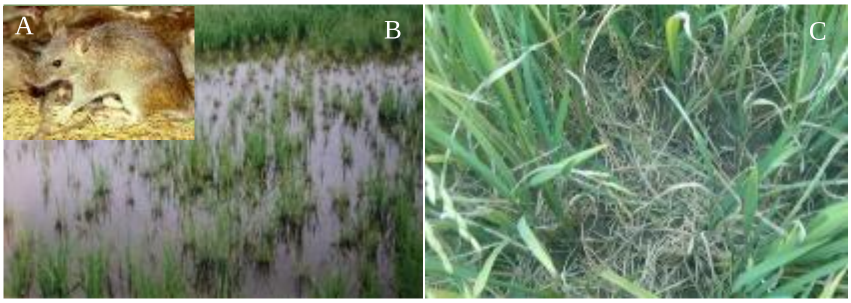


Figure 7: Rice field rat (*Rattus argentiventer*) (A, picture: Grant Singleton), the appearance of the rice field damaged by the rice field rats (B), and ripe panicles cut by rats (C)

Factors favouring rice field rats development

- Availability of food, water, and shelter provided by vegetation;
- Asynchrony of planting of rice crops (greater than 2 weeks) that provides high quality food for longer time;
- Presence of breeding sites (e.g. large banks, scrub vegetation);
- Presence of banks (more than 30 cm wide and 15 cm high), which are suitable for rats to build nests, and village orchards or other crops (sugar cane, maize, etc) adjacent to rice fields.

Rice field rat management

Effective management of rice field rats requires coordinated community actions (e.g. hunting, trapping and clearing of scrub vegetation) to be conducted at early rice production stages (during land preparation and within 2 weeks after sowing) prior to rodent breeding otherwise they will quickly rehabitat where rodent control was already conducted;

Figure 8: Farmers participating in a community action (A, Picture: Dang Thanh Phong, at An Giang provincial Crop production and Plant Protection Department, 2018) and Trap barrier systems (B).

- Take an active part in the community action organized by farmer groups or local agricultural agencies;
- Community action should focus on habitats such as banks, irrigation channels, interior roads, orchards, bushes (**Figure 8A**);
- Apply field sanitation (clear bunds and field edges from weeds) from booting stage until harvest (main rat breeding season).
- Regularly check rice banks to prevent rats from burrowing;
- The use of the Trap Barrier System (TBS) during the rice season at areas that suffer from high rodent damage (>10% damage to rice) will obtain high efficiency. For more information about TBS contact local extension staff (Error! Reference source not found. **B**);
- Chemical baits can be used maximum 2 times to kill the pest from land preparation or crop establishment, and during the tillering stage (before the main rat breeding season). However, safety instructions on package/labels must be complied.
- Rats caught from fields should not be consumed as food during rodenticide application periods.
  - Absolutely do not use electric shock to catch rats because of risks to humans, domestic animals and wildlife.

3.3. Brown plant hopper (*Nilaparvata lugens*)

BPHs are one of rice pests in the rice field and they are considered as the “primary pest”. Both nymphs and adults (long and short-winged BPHs) can damange rice plant by sucking the sap that can make the rice plant dry out and cause hopperburn when high population (Error! Reference source not found.). BPHs are vectors of ragged stunt or grassy stunt virus disease. When BPHs are infected by these viruses they can transmit the diseases until they die.

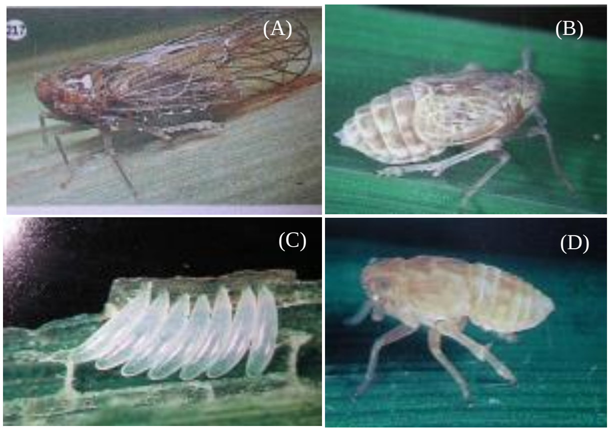


Figure 9: Morphology of development phases of BPHs including long (A) and short - winged adults (B), eggs (C) and nymphs (D)

Factors favoring high BPHs population and outbreak

- Rice crops are grown continuously;
- Susceptible varieties are used;
- High seed rate is used;
- N fertilizer is overused;
- Insecticides are used improperly (early sprays during 40 days after sowing, periodic sprays, etc.)

Brown plant hopper management

- Sow synchronously following ‘escape strategy’ by local agricultural agencies’ recommendations’;
- Insecticides can be only used when necessary, following local agricultural agencies’ recommendations.

* “*The escape trastegy for brown plant hoppers each ricefield or for campartment areas to preventing virus-transmitted diseasea as Rice Grassy Stunt and Rice Ragged Stunt in*

the Mekong Delta" was certified as technical innovation by the national department of Plan protection on Decision No. 325/2009/QD-BVTV dated 17/03/2009. This technique uses of light trap to monitor BPH population in order to identify migrating period of BPH. Rice should only be established when BPH abundance drops after a high peak.

3.4. Small leaf folder (*Cnaphalocrosis medinalis*)

Rice leaffolders usually occur at rice fields where rice is heavily fertilzed, especially after long drought period or where previously farmers use many insecticides (insecticide induced resurgences). Each female lays around 300 eggs attached near by the leaf margin during a life cycle of 3 to 10 days. Larvae start rolling up leaf around them at the late second instar. Each larva can make two to four folded leaves. Pupa is found inside rolled leaf. The larvae feed by scraping off leaf surface tissue resulting in linear white stripe. (Error! Reference source not found.). The damage looks bad, but by themself rarely reduces yields during 40 DAS. For example, damage at 50% of the leaves causes no effect on yield before panicle initiation.

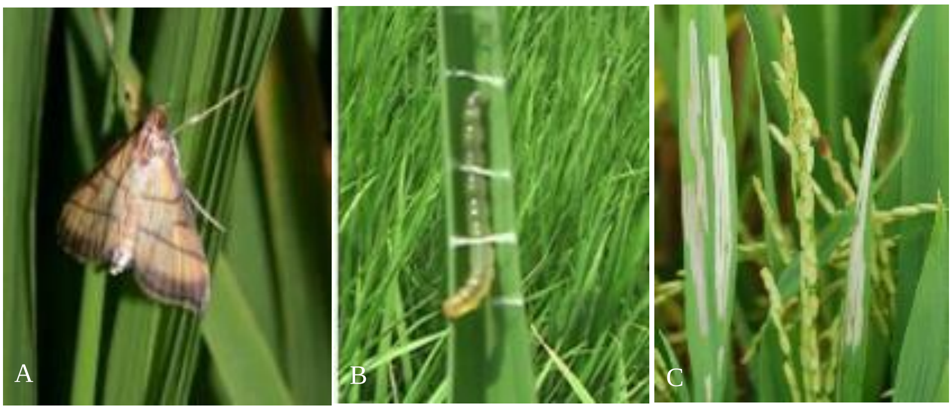


Figure 10: Leaffolder adult (A); Leafolder caterpillar (B); Appearance of leave damaged by leaffolder (C)

This pest is very common in rice fields. If early spray during 40 DAS and period spray are conducted, that will cause resistance to chemicals and inbalance in ecosystem leading to brown plant hoppers' outbreak.

Factors favoring small leaf folder development

- Use high seed rate;
- Overuse N fertilizer;
- High humidity;
- Rice fields are located in shade.

Small leaf folder management

After proceeding the integrated practices mentioned above, if pesticides are still need to be applied, it should be fllowed recommendations' agriculture Agency.

3.5. Stem borer

There are six species of stemborer that attack rice. The yellow stemborer (*Scirpophaga incertulas*) is well known. Stem borers can inflict damage at any stage of the rice plant from the seedling to the maturity stages. They attack tillers and cause deadhearts or drying of the central tiller, during the vegetative stage; and causes whiteheads at the reproductive stage.

Figure 11: Stem borer adult *Scirpophaga incertulas* (Picture: Cuu Long Rice Research Institute, 2018)

Factors favoring stem borers development

- Use high seed rate;
- Overuse N fertilizer;
- Field planted later

Management stem borer (*Scirpophaga incertulas*)

- It is not necessary to use chemical insecticides to control stem borers during the seedling stage and the tillering stages because the rice plant can compensate for the damage caused by this pest
- Regularly visit rice fields to detect egg mases and adults during the panicle initiation and the flowering stages (from heading to finish the flowering);
- Need to detect egg masses of rice stem borers, to assess a threshold for action. Chemical insecticides can be used if there are more than 2 egg masses per m^2

3.6. Panicle rice mite (*Steneotarsonemus spinki* Smiley, 1967)

Panicle rice mite (PRM) appears and causes damage to rice crop throughout the year, but more severe in the summer-autumn rice cropping season (the 2nd rice crop of the year) due to hot and drought conditions. The rice varieties with heavy damage are Jasmine 85, IR50404, OM2517, etc. PRM feeds by perforating the epidermal cells on the inner surface of leaf sheath, husk, and leaf vein of the rice plant, resulting in brown necrotic regions on the effected parts (Error! Reference source not found.). Farmers often call this symptom "Bệnh/vết cạo gió".

PRM is too small to detect with the naked eye. It can be identified in side rice leaf sheath with magnifier at 20 X- magnification. Spider is straw yellow and thickness of about 250μm. Males elongated, very active may be detected on the surface of the leaf. Larva is half a size of adult.

They can cause direct and indirect damage to rice crop as:

- Direct damage: they damage by perforating the epidermal cells. If severe damage occurs during the booting stage would make choking on flowering panicles, partial panicle infertility causing many empty grains (Error! Reference source not found.**D**) leading to significant crop loss.
- Indirect damage: wounds caused by perforating of PRM would favour infection of fungi and bacteria resulting in sheath rot and black-empty grain.

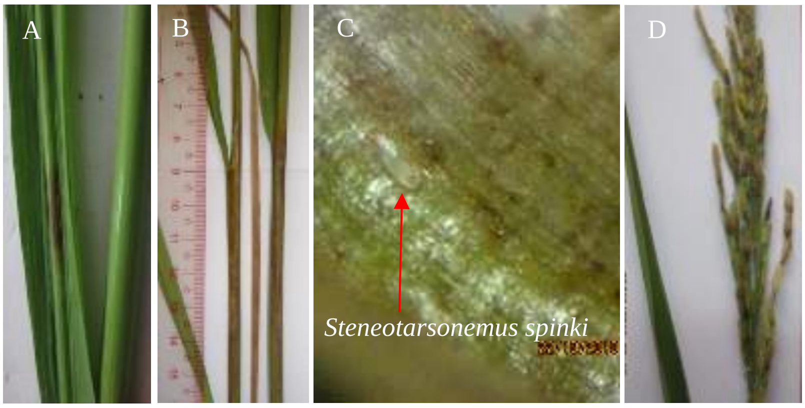


Figure 12: The damage caused by PRM on the leaf vein (A), outer surface of leaf sheath (B), inner hull of the grain, with the appearance of PRM (The PRM photo were taken under a microscope at 40 X magnification) (C), and damaged rice panicle (D). (Picture: Nguyen Trung Thanh, An Giang provincial department of Plant protection, 2013).

Factors favoring PRM development

- Hot and drought condition;
- High relative humidity;
- Rice fields are sown with high seed rate and lack of irrigation water;
- Overuse N fertilizer;
- Early insecticide sprays during 40DAS;

3.7. Rice Caseworm (*Nymphula depunctalis* Guenee)

Rice caseworm usually emerges and causes damage to rice crop from the seedling to the tillering stages. The adults are nocturnal and are attracted to light traps. The moth is about 5 mm long. It is bright white with light brown and black spots (Error! Reference source not found.**A**). Young larvae feed on the surface of tender leaves. The older larva cuts off leaf tip to make leaf case and hides in (Error! Reference source not found.**B**). It then floats on the water surface during the day and crawls to the rice plant with its case to feed at night (Error! Reference source not found.**C**). The larva scrapes the green tissue of the leaf leaving only the white epidermis as ladder-like leaf tissues (Error! Reference source not found.**D**)**.**

Factors favoring rice case-worm development

- Rice fields are continuously flooded;
- Young seedlings are used to transplant.

Figure 13: Caseworm adult (A); Leafcases with larva (B); Floated leafcase on the water surface and larvae in the leaf cases crawing to the rice crop (C); and Appearance of leaf blades damaged by caseworm.

Rice Caseworm management (*Nymphula depunctalis* Guenee)

- Drain water from the fields to kill floating leafcases which have larva inside;
- Young seedlings should not be used for transplanting;

- Rice caseworm larvae are highly sensitive to insecticides.
- Pyrethroids should not be used as the chemicals can cause outbreaks of the brown planthopper.

3.8. Asian rice gall midge (*Orseolia oryzae* Wood-Mason)

The Asian gall midge (AGM) emerges and damage the rice crop throughout the year, mainly from the seedling stage to late tillering stage. Yield loss can vary from 5 to 50% depending on damage intensity. Some fields lose nearly up to 100% although farmers used chemical pesticides many times.

The appearance and size of AGM adult are similar to that of house mosquitoes. Males are brown whereas females are reddish-brown and longer than males (

Figure). Each female can lay from 100-200 eggs during its life cycle. Eggs are laid near the base of leaf blades and leaf sheaths (30 cm apart from water surface)

Young larva of the AGM moves directly into the growing point of rice plant or moves between the sheath and the stem to reach the rice growing point. It damages by feeding on the growing buds of the tiller and release chemicals in its saliva causing the newly developed leaf to become a tubular gall, which appears within a week after larval entry. Elongation of leaf sheaths is called onion leaf or silvershoot and the larva is wrapped inside (Error! Reference source not found.).

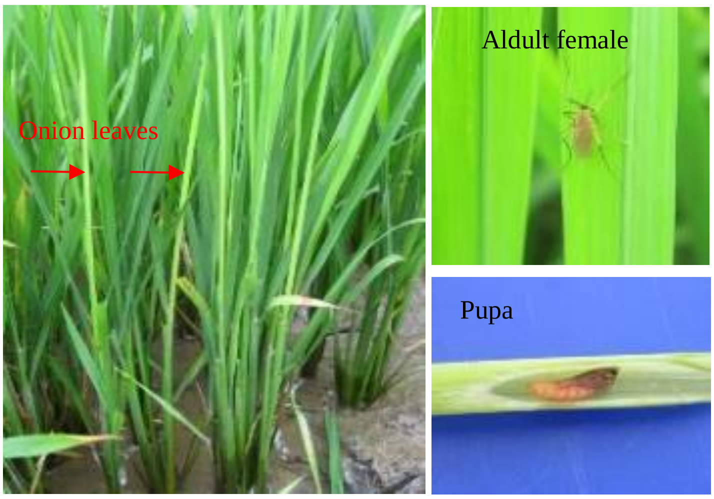


Figure 14: The symptom of tillers damaged by *Orseolia oryzae* and the adult and pupa appearance (Picture: Tran van Duong, An Giang provincial Department of Plant protection, 2014).

Factors favouring Asian rice gall midge development

- Presence of alternate hosts as wild rice, ratooning rice, some different kinds of weeds such as *Echinochloa*, *Leersia*, *Panicum* and *Brachiaria*...
- Warm temperature from 26 -30^{o}C and high humidity from 85-95%;
- Fog and cloudy weather is very favorable for AGM development;
- Unbalanced fertilizer application.

Asian rice gall midge management (*Orseolia oryzae* Wood-Mason)

Well leveled land and well managed water will help facilitate rice emergence and development. This will minimize re-transplanting.

3.9. Sheath blight (*Rhizoctonia solani* Kuhn)

Sheath blight is caused by *Rhizoctonia solani.* It is normally observed after the maximum tillering stage (Error! Reference source not found.).

Factors favoring Sheath blight development

- Presence of the disease in the field soil;
- Presence of sclerotia or infected objects floating on the water;
- Relative humidity from 96 to 100%;
- Temperature from 28-32 °C;
- High seed rate being sown;
- N fertilizer is overused.

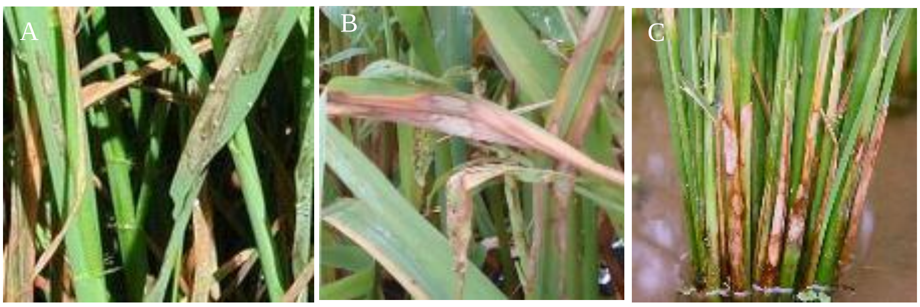


Figure 15: Symptom of sheath blight on leaf blades: newly lessions (A); dry lessions (B) and on the leaf sheath

Sheath blight management (*Rhizoctonia solani* Kuhn)

- Apply Alternate wetting and drying technique;
- If water for irrigation has many water hyacinths infected by *R. solani*, nets should be used to prevent slecrotia, which can float on the water surface, from entering to the field.

3.10. Bacterial leaf blight (*Xanthomonas campestris pv.oryzae*)

Bacterial leaf blight caused by bacteria *Xanthomonas campestris pv.oryzae.* This disease usually appears after the maximum tillering stage onward in the Summer Autumn crop. Initially, water-soaked stripes about 2-3cm long appear below the leaf tip, on the margin of the leaf blade. Stripes enlarge and turn yellow within a few days. One or both leaf margins may have lesions (Error! Reference source not found.).

When the disease develops, lesions cover the whole leaf and the leaf turns white to gray. Bacterial ooze looks like a milky or opaque dewdrop on young lesions can be observed early in the morning (Error! Reference source not found.).

Figure 16: Symptoms of Bacterial leaf blight

Factors favoring Bacterial leaf blight development

- Presence of weeds which are alternative hosts;
- Presence of rice stubbles and ratoons of infected rice plants from the previous season;
- Presence of bacteria in rice fields and irrigation canals;
- Warm temperature, high humidity, storm and high water level;
- High seed rate is sown;
- Overuse of fertilization.

Figure 17: The appearance of bacterial drop and the rice field damaged by bacterial leaf blight (Picture:Tran Van Duong and Dang Thanh Phong, An Giang provicial Department of Plant protection, 2014).

Bacterial leaf blight management

Planting resistant varieties is the most efficient, most reliable way to control bacterial blight.

Other options to control the disease as:

- Use Bacterial leaf blight tolerant variety;
- Seed treatment can be practiced (mentioned in Section 3);
- Use balanced amounts of plant nutrients, especially nitrogen (110kgN/ha is maximum amount should be used).
- Ensure good drainage of fields (in conventionally flooded crops) and nurseries.
- Keep fields clean. Remove weed hosts and plow under rice stubble, straw, rice ratoons and volunteer seedlings, which can serve as hosts of bacteria.

3.11. Rice Blast (*Magnaporthe grisea*)

Rice blast or leaf burning is caused by *Magnaporthe grisea, previously known as Pyricularia oryzae.* Rice blast infects the rice plant at any growth stage. The disease occurs throughout the year in different climate areas. The fungus affects leaf, panicle neck, node, panicle, grains. High damage usually is caused leaf and collor. The characteristic symptoms as:

On rice leaves called leaf blast: the symptoms start with the appearance of small whitish, greyish or bluish spots of 1-3 mm diameter on the leaf blades (Error! Reference source not found.). When the disease develops, these lesions will be enlarged connecting together. This will cause infected leaves burning over a large area.

On node of the rice plant called stem/culm blast: initial lesions are small black dots which develop and encircle the nodes causing the nodes rot (Error! Reference source not found.**A**).

On neck of the rice panicle called neck blast or neck rot: the disease is usually appreas late at the late grain filling stage causing the panicles to break at lesion and to become white in colour – the so-called 'white head' (**Figure 19B**).

Figure 18: Symptoms of blast on leaf (Source: An Giang provincial department of Plant Protection, 2012)

Factors favoring disease development

- Susceptible varieties are grown;
- Use high seed rate;
- Rice is over fertilized, especially N fertilizer;
- The symptoms of blast on leaf blades have been found in the field;
- Rainy or cloudy weather with high humidity and heavy dews during the flowering stage.

F**igure 19**: The appearance of node blast (A), and panicle neck blast and leaf collar (B)

Rice blast management

- Use resistant varieties;

- Approriate sowing density;

- Use balanced amounts of plant nutrients, 110kgN/ha is maximum amount should be used;

- Synchronous sowing as recommended by the local agriculture agency;

- Clean up the source of the disease spread as infected plants, the secondary hosts;

- Use plots as forcast to monitor the development of disease, if the disease spread quickly in the predicted plots, the field shoul be irrigated and apply fungicides following the right 4 as recommended by agriculture agency.

3.12. Grain color discoloration

Grain colour discoloration is the common name to refer to rice grains with the rice husk discoloration. Dots of brown to black appear on rice husk. These dots can enlarge and cover the whole the rice husk, resulting in significantly reduced rice quality and productivity.

There are many factors causing discolouration on rice consisting of fungus, bacteria, insects, spiders, effects of weather, agricultural practices, etc. (**Figure 20**). There are currently about 12 different types of fungus causing discolouration as *Helminthosporium* sp., *Curvularia lunata*, *Saracladium oryzae*, *Alternaria tenuis*, *Fusarium moniliforme*, *Cephalosporium* sp., and *Phoma* sp.

Figure 20: Grain colour discoloration appearance (Picture: Dang Thanh Phong, An Giang provincial Department of Plant Protection, 2014).

Factors favoring development of grain colour discoloration

- Incessant rains;
- High humidity and cloudy weather during the heading to the milky stages.

Grain colour discoloration management

- Control insect pests causing damage to rice grains during the flowering and maturity stages;
- Store rice grains at the moisture content from 13.5-14%.

3.13. Yellowing syndrome

The rice plants will suffer from yellowing syndrome when tillers of plants are mix-infected with RGSV and RRSV. Viruses persist in the body of the brown plant hopper until death. The disease usually occurs early during the seedling stage. The diseased tillers are shorter and tilted, while the leaves showed bronzing and occasional yellowing that appear from the tip and from the edge of the leaves (Figure 21). The disease can result in damaged rice roots leeding to the death of rice plants. Severe disease will severely reduce crop productivity.

Figure 21: Appearance of Yellowing syndrome in the rice field (Picture: Dr. Ho Van Chien, Sounthern Regional Plant Protection Center/SRPPC, 2009)

Factors favoring development of yellow syndrome

- The occurrence of BPH carrying virus,
- Rice crops are grown continuously,
- Asynchronous planting or sowing of crops,
- High seed rates (direct seeding),
- Overused nitrogen application,
- Overuse of pesticides.

Yellowing syndrome management

Yellowing syndrome, Rice Grassy Stunt and Rice Ragged Stunt are the virus diseases transmitted by BPH. There are no specific pesticides for their control, so implementing preventive practices against the diseases is more efficient than direct-control measures. In addition to the use of IPM, the following practices need to be applied:

- ✓ Farmers should follow practice of 3G3T to keep rice plants healthier. Use of less nitrogen fertilizers can make the cultivation conditions unfavorable for pest occurrence,
- ✓ Apply practices to manage BPH,
  - ▪ Use resistant variety to BPH,
  - ▪ Use light traps to monitor BPH migration in order to apply the crop escape or avoidance strategy,
  - ▪ Synchronized planting,
    - o At seedling stage within 20 days after seeding, plants are very susceptible to virus infection. Crop establishment using direct seeding could be done during migration time (5-7 days in average) or just after the migration ends. For transplanting, seedlings should be covered by nylon mosquito net during night time and removed in the morning. Seedlings should be transplanted right after the migration ends.
  - ▪ Only use chemical insecticides when necessary;
    - o Insecticides can be applied to lower BPH population. However, RRSV and RGSV can be transmitted by BPH within 5-15 minutes at

night time after landing in the rice field, thus even insecticide application may not help,

- ✓ Eradication of diseased plants in fields/ Plow infected stubbles under the soil after harvest to destroy the virus source.

3.14. Rice Grassy Stunt

The disease is caused by Rice Grassy Stunt Virus (RGSV). The infected rice plants are severely stunted, excessive tillering, very upright plant, grass appearance, yellowish green leaves which are shorter and narrower than healthy leaves. The leaves remain yellow even after sufficient nitrogen application. Rusty spots appear on leaves that can be linked to patchs. Infected rice plants fail to produce panicles (**Figure 22A**).

Brown plant hoppers including adults and larvae are vectors for rice grassy stunt virus. However, the virus is not transmitted via BPH eggs. BPH needs to feed on infected rice plants at least for 30 minutes to get the virus. It will take about 10-12 days for the symptoms to appear in the infected rice plant.

Plants can be infected at all growth stages but the tillering stage is most vulnerable to infection. Infected stubbles and volunteer rice are source of infection.

The syptoms of stunt and excessive tillers can be confused for symptoms of rice yellow dwarf and rice dwarf disease. Therefore, check for prominent mottles on the leaves and grassy appearnace of plants to affirm Rice Grassy Stunt Virus.

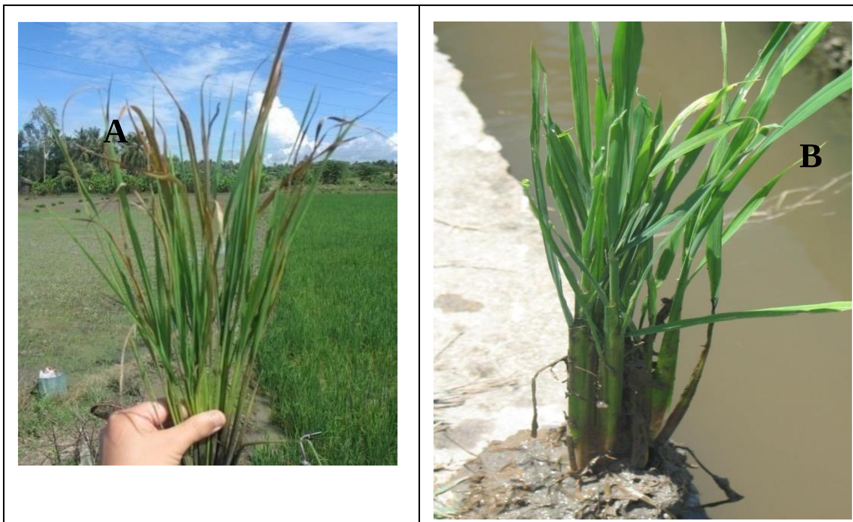


Figure 32: Appearance of Grassy Stunt (A), and Ragged Stunt (B) in the rice field (Picture: Dr. Ho Van Chien, SRPPC, 2009)

Factors favoring development and Management of RGSV (same as that of Yellowing syndrome)

3.15. Rice Ragged Stunt

This disease is caused by Rice Ragged Stunt Virus (RRSV). Infected rice plants are severe stunted, have dark green leaves, serrated uneven leave edges, swollen veins, and twisted and malformed leaves (**Figure 22 B**). The infected plants fail to produce panicle or produce unfilled grains leading to reduction in yield.

The younger BPH larvae of BPH can transmit RRSV more effectively than older ones. BPH can pick up the virus after feeding on the infected rice plants for 24 hours and they can transmit virus to other plant after 6 hours of being infected and remain infective for life. However, the virus is not transmitted via BPH eggs. Infected stubbles and volunteer rice are infective sources.

RRSV can affect up to 75% of plants in a crop. Depending on the extent of the damage infected plants will either produce partially exerted panicles and unfilled grains or produce few or no grains. Infected crops will suffer significant yield losses of up to 80%.

Factors favoring development and Management of RRSV (same as that of Yellowing syndrome).

4. Ecological engineering for pest management in rice crop

4.1. What is ecological engineering about?

Ecological engineering (EE) is defined as "the design of human society with its natural environment for the benefit of both". This is an approach to restore or enhance biodiversity of floral and faunal species in the rice landscape. This helps to create food chains and food webs in a dynamic but balanced eco-system; also referred to as an "Ecological Service". From this chain of ecosystem services, natural enemies will attack the pests and maintain pest populations below the threshold that can cause economic damage. The end result is rice growers will not need to use pesticides.

4.2. Main measures to restore or enhance biodiversity

EE technique can be implemented by planting nectar-rich flower plants on the bunds surrounding rice fields. The nectar is a good food source for bees, wasps and other species that can enhance the pollination of fruit crops in the rice landscape. Also, the nectar attracts many hymenopteran parasitoids; especially those predators that regulate rice pest species, such as planthoppers, leafhoppers, stem borers, and leaf folders.

Figure 23: Examples of ecological engineering for pest management (Source: An Giang provincial Department of Plant Protection, 2014).

4. 3. Main Benefits of implementing 'Ecological engineering'

- ✓ Rice fields enriched with nectar-rich flower plants have significantly higher parasitism and predation of planthopper eggs. More than 80% of parasitized BPH eggs are found in rice fields that practiced EE;
- ✓ Substantial increases in profits from reduction in insecticide use but harvest similar or higher yields;
- ✓ Have extra vegetables for family meals;
- ✓ Create a beautiful rural landscape.

- *Note: rice fields, which have large-sized banks and irrigation water initiative shoud be chosen in order to facilitate the care of flowers. Priority should be given to areas where three-rice crops are grown in a year.*

SECTION 4: MECHANIZATION AND POSTHARVEST MANAGEMENT SUPPORTING 1M5R

There are many advanced technologies introduced globally that can support 1M5R. Within this manual, we highlight the major mechanization and postharvest systems that significantly support the five reductions of the 1M5R. Detailed manuals and published documents of these systems can be requested through (postharvest@irri.org). Laser-controlled land leveling (laser leveling) is a precise leveling technology applyed to reduce land inclination thus directly increases water use efficiency and indirectly supports saving of other agronomic inputs. Mechanical transplanting reduces significantly seed rate and reduces other agronomic inputs. Laser leveling and mechanical transplanters each indirectly reduce postharvest losses. For directly reducing postharvest losses, we would introduce the scalable and well adapted technologies such as combine harvester for harvesting; flatbed dryers and fluidizedbed in combination with columnar dryers for paddy drying, and hermetic and aeration technology for paddy storage.

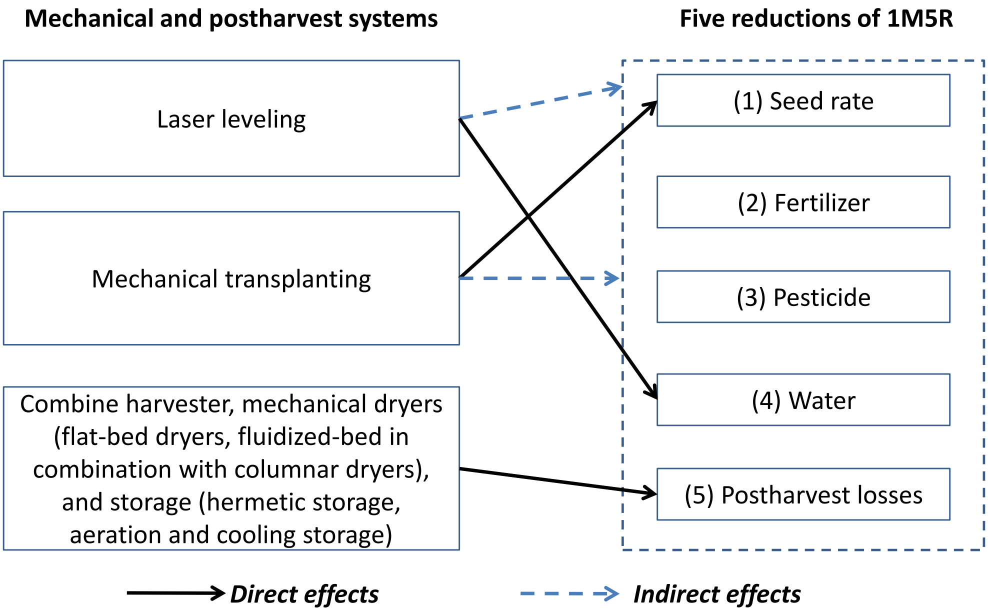


Figure 24. Supporting pathway of mechanization and postharvest systems on 1M5R

1. Laser-controlled land leveling

(Training manual can be requested through postharvest@irri.org)

What is it and how does it work?

Laser-controlled land leveling (LLL) is a precision technology used for leveling the field to desired slope using a guided laser beam that controls the height of the tool attached to a tractor. **Figure 25** shows the key components a LLL. A laser transmitter creating a horizontal laser plane above the field is placed at the side of the field. A laser receiver mounted on the drag bucket measures the height of the drag bucket relative to the laser plane and, through some electronic and hydraulic controls, adjusts the height of the drag bucket according to the signals received. The mechanism keeps the drag bucket always at the same height (**Figure 26a**), resulting in soil being scraped off (**Figure 26b**) and collected from the elevated areas of a field and getting dropped in the low areas (**Figure 26c**).

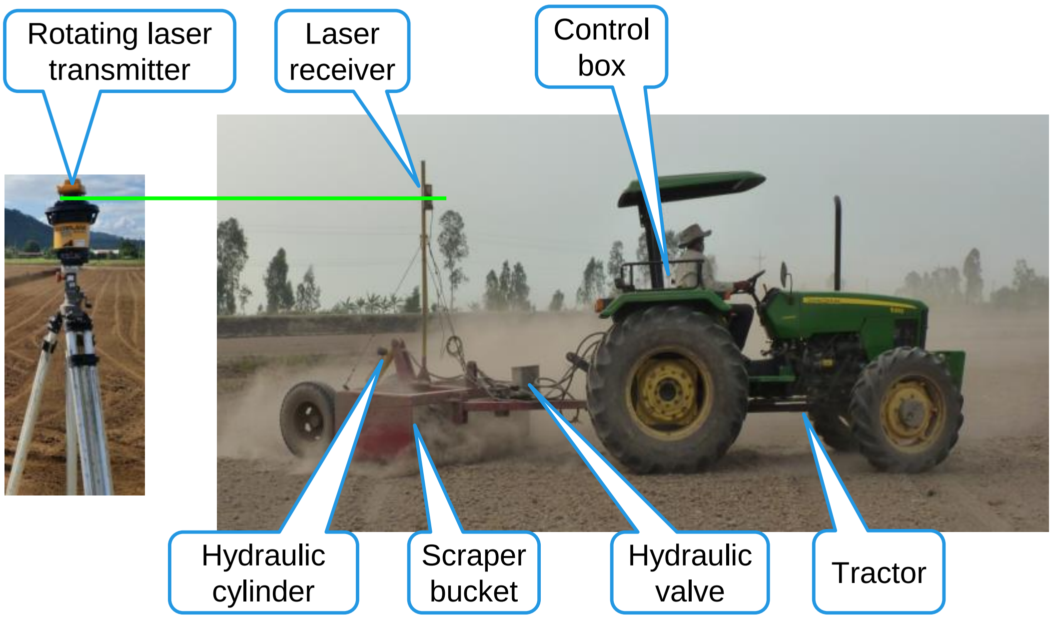
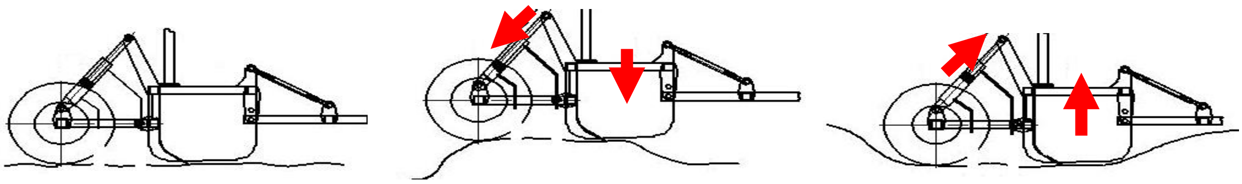


Figure 25. Key components of LLL



a. Scraper at the average (middle) position ➔ maintained

b. Scraper at high position ➔ lowered to collect soil

c. Scraper at low position ➔ raised up to release soil

Figure 26. Scraper of LLL at the three working status

Why is it needed and what are the benefits?

Small-size and uneven fields can cause poor management and low use efficiency of agronomic inputs. They also hamper mechanization and cause rice plant lodging and non-uniform paddy at maturity stage leading to high postharvest losses. For example, assuming a small and a large field with the same slope, the larger dimension causes the higher unevenness (**Figure 27a**) resulting in poorer management of water, fertilizer, pesticide, and lodging (**Figure 27b**).

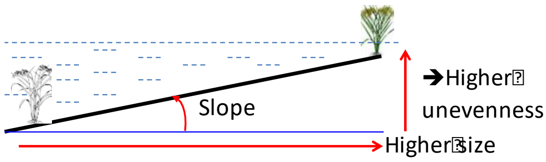


Figure 27a. Slope and plot size

Figure 27b. Poor leveling field causing crop establishment difficulty (left) and lodging (right)

LLL can reduce the unevenness level of the field to 1-2 cm, even in a large field with for example 3 ha, the field slope for draining the field can be set to 0.02%. Application of this technology can lead to an increase by 20% of land use efficiency when consolidating small field to large fields; savings of 20–60% irrigation water; increases of 5–10% in fertilizer and pesticide-use efficiencies; yield increases of 5–15% in rice. Benefits of LLL from field trials in India and Vietnam are summarized in **Table 3**.

Table 3. Benefits and conversion factors of LLL

Benefits	Percentage of benefits (%)
Area increase when consolidating small field to large fields	3-6[a,b,c]
Water saving	20-40[a,b]
Saving diesel for pumping water	30-60[c,d]
Reduction of seed rate	40[c,d]
Saving fertilizer and pesticide	10-13[a, b, c, d]
Yield increase	5-15[a,b.c]
Reduce postharvest losses of rice produced	2-5[c]

**Lower values of the benefit ranges (%) were used to calculate this column*

a = Jeetendra and Jat (2015), b=RKB (2017), c= Hien et al. (2014), d=Khanh et al. (2013)

2. Mechanical transplanting

(Training manual can be requested through postharvest@irri.org)

What is it and how does it work?

Rice can be established by several methods depending on the available resources and ecosystem. In areas where labor is sufficient and cheap, the customary way is to establish the crop in a nursery for 2-3 weeks before it is transplanted in a puddled field. In situations where labor is lacking and expensive, direct seeding or mechanical methods are options to ensure timely establishment of the rice crop. Other factors that affect the decision of crop establishment method are the availability of water, and the field conditions (e.g., field levelness, seed quality). Transplanting of rice seedlings can be done either manually or using a machine. Transplanted crops will normally take less time in the production field but 10–15 days longer for the total crop duration. A well prepared seedbed is needed to have better seedlings. Machine transplanting (**Figure 28**) of rice seedlings takes less time and is less labor intensive, compared to manual transplanting. Other benefits are an improved seedling establishment and a uniform maturity. For the transplantation with the machine, seedlings are nursed for 12-15 days in advance. The fields should be well puddled, leveled and drained to prepare a good seedbed and to allow a proper operation of the machine.

Figure 28. Transplanting rice by use of mechanical transplanter

A well prepared seedbed for crop establishment requires good land preparation at the right duration and timing:

- Cultivator or power tiller at a depth of 5-7 cm on the first pass. Secondary workings can be done with a tandem disc harrow.
- Well leveling the field (e.g. using laser leveling system)

Why is it needed and what are the benefits?

Transplanting rice on a puddled field has several advantages to the farmer over the direct seeding method of crop establishment, which includes the following:

- The risk of seeds being eaten in the field by birds and rats
- Better weed control. Rice seedlings have a headstart with weeds in the field so it will be not much of a problem. When the field is well-leveled, weeds can easily be controlled with better water management.
- Allows deeper anchorage of roots into the soil, thus, less likely to have lodging effect throughout the growth of the crop.
- Low seed rate is achieved with transplanted rice as it can be properly controlled and managed during the raising of seedlings in the nursery.
- Uniform crop stand can easily be achieved especially in a well-leveled field.

When labor is limiting and expensive, the use of machine in transplanting is more advantageous. In manual transplanting of rice around 20-30 persons are needed to cover one hectare per day as compared with mechanical transplanter that would need two (2) to three (3) operators to accomplish transplanting 1-2 hectares in one day. The advantages that can be derived with the use of mechanical transplanter in establishing rice in the field are the following:

- Efficient use of resources by saving labor cost

- Timely transplanting of seedlings at optimal age
- Reduced transplanting shock
- Ensure uniform spacing and optimum plant density (26-28 hills/m2)
- Higher yield compared to traditional method (e.g. manual broadcasting)
- Lower drudgery and health risks for farm laborers
- Improved employment and entrepreneurship opportunities for rural youth and women through custom service provision
- Increase in rural income and livelihoods

3. Combine Harvester

(Training manual can be requested through postharvest@irri.org)

What is it and how does it work?

Combine harvester is a self-propelled machine combining all the traditional operations of harvesting such as cutting, gathering, threshing, and separating (**Figure 29**). Threshing is done by a rotating drum or rotor, with a concentric concave adjacent to it. The height and speed of the reel, and the angle of the fingers, are adjusted to match the condition of the crop to minimize losses and maximize the efficiency of the machine.

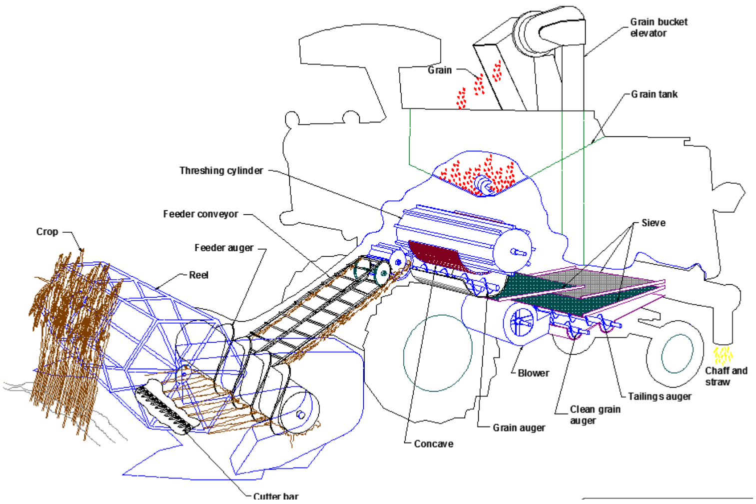


Figure 29a. Components of a combine harvester.

(Source: Gummert et al., 2018)

Figure 29b. An operating combine harvester

Why is it needed and what are the benefits?

Combine harvesting with its advantages of capacity, combination of different operations, etc. can solve the issues in manual harvesting such as labor shortage, losses caused by delay of harvesting time, unnecessary transportation of rice plants from harvest areas to the threshers, etc. According to Gummert et al. (2018), combine harvesters can potentially reduce harvesting losses to 1–2% as well as overcoming physical labor shortages at harvest resulting in reduced harvesting cost of 50% compared to manual harvesting and threshing (**Table 4**). A case study in Vietnam shows that for dry and wet field conditions, the cost of combine harvesting is US$56 and US$83, respectively, per hectare while that of traditional practice is US$140 and US$160/ha, respectively. The difference between the cost of combine harvesting and the cost charged to farmers for the service means that the payback time for combine harvesters in some parts of Asia, if effectively managed with sufficient area harvested, is approximately 2 years.

Table 4. Component cost (US$/ha) of different harvesting practices (adapted from Gummert et al., 2018)

Cost components	Manual harvesting & mechanical threshing		Combine harvesting	
	Dry	Wet	Dry	Wet
Depreciation & maintenance	1.1	1.3	17.5	26.3
Interest	0.2	0.3	3.5	5.3
Fuel	14.0	17.7	25.9	38.8
Labor	126.0	141.6	8.8	13.1
Total harvesting cost	*141.3*	*160.9*	*55.7*	*83.5*

4. Mechanical drying

(Training manual can be requested through postharvest@irri.org)

What is it and how does it work?

Wet paddy at harvest with high moisture content (MC) needs to be dried to reduce the MC for safe storage (usually at 14% MC wet basis) to avoid quality deterioration, discoloration, mold, etc. We introduce two types of drying systems including flatbed dryer (FBD) for comunity scale and the two-stage drying systems for industrial scale.

Flatbed dryer (FBD)

A FBD consists of three main components including blower, furnace, and drying chamber (**Figure 30a**). Grain is placed in a rectangular bed on a perforated false floor. The furnace heats ambient air, which is sucked by a fan and pushed through the grain mass until it exits from the grain mass surface. The drying process continues until the grain mass is dried to the desired moisture content, usually 14%. A FBD with the drying air moving in one direction (usually upwards) is called conventional flatbed dryer (FBDc), while that with drying air moving in two directions, upward and downward, is called reversible airflow flatbed dryer (FBDr) (**Figure 30b**). Drying material is loaded into the drying bin with a depth of 25–40 cm and 50–60 cm on a perforated floor for the FBDc and FBDr, respectively. Drying air temperatures are in the range of 42–45^{o}C for grain and 40–43^{o}C for seed production, respectively. This dryer is developed by Nong Lam University and adapted widely in Vietnam (Phan-Hieu-Hien et al., 1995 and Phan-Hieu-Hien et al., 2003).

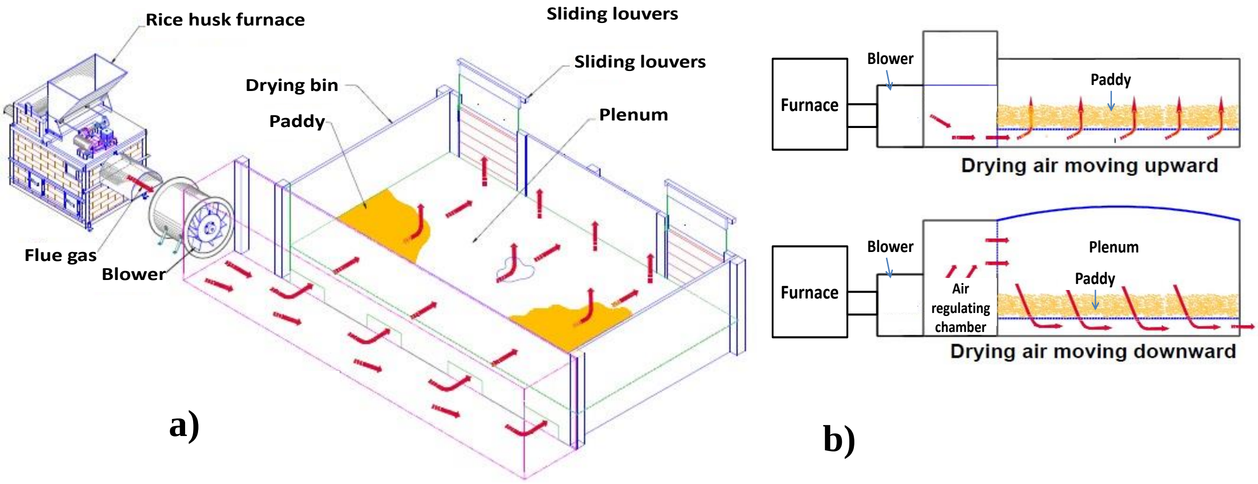


Figure 30. Flat bed dryer (FBD), (a) Scheme of FBD; (b) principles of FBDc and FBDr

(source: Nguyen et al., 2018a)

Recirculating columnar dryer (RCD) and Fluidized-bed dryer (FLBD) in combination with RCD

Fluidized-bed dryers (FLBD) in combination with recirculating columnar dryer (**Figure 31**) are usually used for industrial scales with a capacity higher than 200 t/day (RKB, 2016; Nguyen et al., 2018b). In fluidization process, hot air is blown at high pressure through a perforated bed of wet grain. The wet grain are lifted from the bottom and suspended in a stream of air (fluidized state). Heat and mass transfer is accomplished by direct contact between the wet grain and hot air. Moisture is carried away by the drying air. In some designs of FLBD, the exit air is partially recycled to save energy. The FLBD dries paddy at the first stage, usually to reduce its MC from 24-28% to 20-22%. Wet paddy passes through the drying chamber of the FLBD within 2–3 min. The FLBD is used with a drying temperature of about 60–75^{0}C, mainly for pre-cleaning wet paddy and reducing its maximum MC by 2–3%. At the second stage, paddy is then loaded into RCDs. The FLBD works continuously while the RCD works as a batch-recirculation. In the first 30 minutes of RCD drying stage, paddy is being tempered by unheated air blown from the RCD's fans within 1 hour. The paddy is then dried in the recirculating batch of RCD within 6-8 hours down to 14% of MC. A FLBD with a capacity of 30 t/h can be connected to 10 RCDs with the capacity of 30 t/batch for each unit.

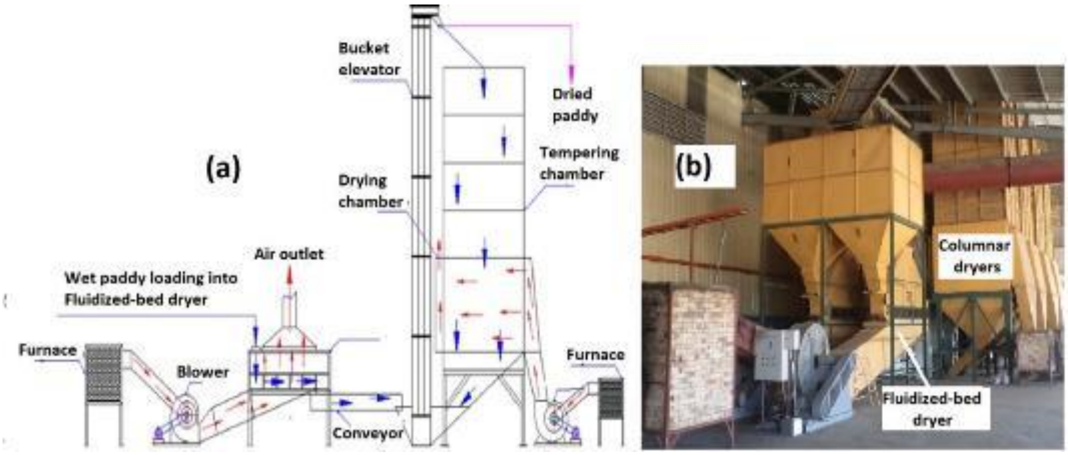


Figure 31. Two-stage drying system, (a) schematic diagram and (b) photograph of the system in operation *(Source: Nguyen et al., 2018b)*

Why is it needed and what are the benefits?

After harvesting, the paddy should be dried as soon as possible, ideally within 24 hours using proper drying methods, to reduce its MC to about 14%, which is the safe MC to prevent paddy losses from respiration, germination, etc., during storage. Using mechanical dryers besides solving labor shortage problem can avoid grain losses caused by handling, weather, etc. in manually sun drying of rice. The mechanized practices potentially reduce losses by 2-5% compared to sun drying. A case study on comparing cost of different drying practices is shown in **Table 5**.The RCD and two-stage are not applicable at the farm level.

Table 5. Drying cost ($US/t) for different drying systems (adapted from Nguyen et al., 2018b)

Cost components	Sun-D	FBDc-4	FBDr-20	RCD-30	Two-Stage
Depreciation, maintenance, and interest	-	3.5	2.4	4.8	3.0
Labor for drying operation	20.0	2.5	0.5	0.4	0.1
Labor for loading and unloading	5.0	2.5	1.5	0.4	-
Electric power	-	1.2	0.9	0.8	0.9
Rice husk consumption	-	2.4	2.4	3.0	3.5
Total	*25.0*	*12.1*	*7.7*	*9.4*	*7.5*

Sun-D = Sun drying; FBDc-4 = Flatbed dryer 4 t/batch; FBDr-20 = Flatbed dryer 20 t/batch; RCD-30 = Recirculating columnar dryer 30 t/batch; Two-stage = System of FLBD in combination with RCD 200 t/batch.

5. Grain storage

(Training manual can be requested through postharvest@irri.org)

What is it and how does it work?

Poor storage management and facilities allow grain to reabsorb moisture and be attacked from insects, fungi, rodents and birds. Physical losses during storage often account for 10-15% of the total grain harvested. Losses in quality result in lower germination (seeds) and poorer eating attributes which also devalue the end product. Storability of grains depends many factors like insect and fungi infestation, temperature, and moisture content.

Hermetic storage, introduced within this manual, is a technology based on the principle of airtight enclosure, preventing oxygen penetration inside the bags. With this, insects die or become inactive under non-oxygen condition of hermetic storage. It can be operated without power, and does not require pesticides for fumigation to reduce loss and preserve grain quality. Respiration by the grain and insects reduce the oxygen level and increase CO_2, which kills the insects. Hermetic systems can increase head rice by 10% and double the viability of seeds. Sealed storage containers come in all shapes and sizes (**Figure 32**). They may range from a small plastic container, like a sealed 200-liter drum, to the more complex and costly sealed plastic commercial storage units with 1-1,000 ton capacity per unit. Hermetic Super bags with 50 kg capacity are now also commercially available and widely used.

Figure 32. Hermetic storage systems made from locally available containers (left); the hermetic IRRI Super bag for 50kg (center); and a hermetic Cocoon™ with 5t capacity (right)

Why is it needed and what are the benefits?

Poor rice storage facilities can cause product loss from 2% until it becomes waste. Poor paddy and rice storage result in quantity loss caused by birds, rodents, and other animals and quality deterioration that is depicted by brokenness, discoloration, and aflatoxin contamination.

6. Rice straw management

6.1 Burning issues and alternative management options

Rice cropping system intensification with shorter turnaround time and the rapid introduction of combine harvesters constitute a game changer of rice straw management because combines leave the straw spread out on the field. Manual collection is unprofitable because of the high labor cost. Incorporation in the soil is also not possible in intensive systems with two to three crops per year because the turnaround time is too short for decomposition. As a result, **open-field burning of straw has increased dramatically over the last decade**. Improved by-product management and technologies that can help reduce the environmental footprint of and increase revenues from rice production. Rice straw in principle can be processed and used in agriculture for purposes such as soil improvement through carbonization and composting, in bio-energy production, and to produce materials for industrial uses such as silica and bio-fiber. However, not all the options are economically feasible because the costs of products produced from rice straw, including transportation cost, are still higher than for products produced from the other traditional or existing feedstocks. Competitive-scalable options for rice straw such as composting and mushroom and cattle feed production are introduced within this manual.

6.2 Scalable solutions for sustainable rice straw management

a) Mechanized collection

(Training manual of straw balers can be requested through postharvest@irri.org).

Straw needs to be gathered from the field and compressed into bales to make it compact and easy to transport. **Figure 33** shows three types of rice straw collection machines those widely used in the Mekong River Delta of Vietnam (MRD). A round baler (**Figure 33a**) is a machine that collects and compacts rice straw into round bales. Self-propelled baler (**Figure 33b**) both makes and transports bales to the bund. This machine moves on rubber chain wheels that allows it to be used on wet fields. Loose straw collection machine (**Figure 33c**) can be used to collect scattered straw on the field. This machine is usually self-propelled and is easy to operate.

Fig. 33a. Round baler.

Fig. 33b. Self-propelled baler.

Fig. 33c. Loose-straw collection machine.

Cost of straw collection is 12-15 $US/ton while the service fee in the area is 16-20 $USD/ton.

b) Mushroom production

(Training manual of straw balers can be requested through postharvest@irri.org).

Rice straw mushrooms, *Volvariella volvacea*, are considered to be one of the easiest mushrooms to cultivate because of their short incubation period of 14 days. This tropical species thrives best at 30–35 °C for mycelia development and at 28–30 °C for fruiting body production. The main inputs for mushroom growing are rice straw, spawn, labor, and water. Harvest of mushrooms usually starts in the third week and ends in the fourth week after inoculation. Outdoor mushroom production (**Figure 34a**) is a common practice in the MRD. The low investment cost is an advantage of this practice. It produces a yield of 0.8 kg of mushroom per 10 kg of dried straw and generates a net profit of USD 50–100/ton of straw. Indoor mushroom production (**Fig. 34b**) is a less common practice because it requires a higher investment cost and strict control of growing conditions. On the other hand, indoor mushroom growing produces about 2 kg higher yield per 10 kg of dried straw and generates a net profit of USD 100–120/ton of straw.

Fig. 34a. Outdoor mushroom growing.

Fig. 34b. Indoor mushroom growing.

c) Rice straw silage for cattle feed

Rice straw has too few nutrients to be used as the only source of food for cattle but is a good feed additive and can also be treated to increase the supply of energy and protein. In general, the daily recommended maximum intake of rice straw by ruminants is 1.0 to 1.5 kg per 100 kg liveweight per day. rice straw is ensilaged in bulk with 2-4% lime and 2-4% urea to produce better feed (**Figure 35**). The product can be used after 2-week ensilaging.

Figure 35. Preparation of rice straw silage (left) and feeding (right).

d) Mechanized composting

(Technical report of rice straw based composting can be requested through postharvest@irri.org).

Compost is produced based on mixing of rice straw, animal manure, and enzymes using the turner (**Fig. 36**) and ensilage to optimize the composting process. This technology has been developed by the IRRI – sustainable rice straw management project.

Features:

- Capacity of the composting system: 25–30 t/hour
- Optimized composting process and ration composition of C/N = (25-30)/1

- Enhances nutrient (i.e., nitrogen and carbon contents) and organic matter content of the soil
- Compost material can be used as medium for growing vegetables and other crops or spread on the rice field as soil amendment.

Figure 36a. Compost turner–front view.

Figure 36b. Compost turner–rear view.

SECTION 5: SMALL FARMERS, LARGE FIELD – SFLF

(*Based on criteria for establishing of SFLS, Crop Department 2012*)

1. What is SFLF?

SFLF means '*Many farmers in a large field'*. In other word, it is a new approachthat promotes the linkage of producing and marketing that is encouraged to be implement in agricultural production. (Decree No. 98/2018/NĐ-CP**).** The premise is that this will generate rice production of high quality for export following standards as stipulated under 1M, 5R, VietGAP, GlobalGAP, SRP, etc.

2. Benefits of SFLF

- To be able to implement synchronously and efficiently advanced techniques over a large area;

- To close the gap in productivity among households, fields, compartment areas; also to improve the average rice yield in the region (close yield gaps);

- To have farmers and FOs better integrated with the rice value chain.

- To improve the quality and value of rice.

- To contribute to stable production and marketing of rice products.

3. The requirements for establishing SFLF model

- ✓ SFLF must belong to the overall plan for agricultural and rural development at a locality. The place where SFLF will be established needs to have a good irrigation system, the presence of extension staff, relatively good farmers' farming practices;
- ✓ SFLF should require an area ≥ 300 ha comprising adjacent small fields;
- ✓ Internal irrigation systems are completed. This facilitates good irrigation and drain control;
- ✓ Favorable geographical location for the organization of rice production and transport;
- ✓ The rights of farmers are guaranteed;
- ✓ Famers' participation is voluntary;
- ✓ Availability of transport systems to facilitate mechanization in rice production from land preparation to harvest, preservation and storage;
- ✓ One or more forms of linkage between enterprises and farmers and FOs; and between enterprises and enterprises (input supplying companies and rice exporter companies).
- ✓ Training on farming techniques relating to pre- and post-harvest need to be provided to farmer participants;
- ✓ Farmers have to implement entirely 1M, 5R;
- ✓ 100% area implement mechanized harvesting;
- ✓ 100% rice productivity is dried properly in the Summer-Autumn and Autumn-Winter rice cropping season;
- ✓ The SFLF needs to have participation of input businesses including pesticide, fertilizer, seed and marketing businesses including companies relating to buying and selling rice. Also, effective links are needed between business and business, between farmers and farmers, and between businesses and farmers. These links are carried out via a contract between the organizations; businesses and FOs;
- ✓ The agreement shown in farming contracts must comply with existing laws;
- ✓ Local agricultural agencies directly organize SMLF implementation;
- ✓ The enquiries and difficulties which arise during the implementation process should be discussed among the parties according to mutual benefits.

SECTION 6: SUMMARY AND NOVEL PRACTICES

Some of the practices described above are available as videos on YouTube on the IRRI Videos link https://www.youtube.com/user/irrivideo/videos?flow=grid&view=0&sort=p

Videos of note include :

Vietnamese--Cách kiểm soát các loài chuột đồng (How to control ricefield rats)

https://www.youtube.com/watch?v=bUeyhA9eMS8

Laser leveling –Introduction of laser levelling of ricefield

https://www.youtube.com/watch?v=bdJxOtld2Ps&list=PLNowyW0S1hI8ZpQhaUQi4zHcuKWqCBsRp&t=0s&index=22

Alternate wetting and drying (AWD) – English version only

https://www.youtube.com/watch?v=tfKWKfagfFs

Technologies for rice straw management

https://www.youtube.com/watch?v=ELnSqk1oGYA&list=PLNowyW0S1hI8ZpQhaUQi4zHcuKWqCBsRp&t=0s&index=49

Besides the adopted and scalable practices and technologies mentioned above, there are recent developments on avanced technologies that support for 1M5R. Following are some of the highlighted introduced technologies for rice production :

- Web-App Rice Crop Manager for site specific nutrient management, Beta version for Vietnam: http://webapps.irri.org/vn/rcm/
- Mechanical spreader for fertilizer application (http://ghgmitigation.irri.org/technologies/fertilizer-spreader)
- Web-App EasyHarvest, proof-of-concept for optimized scehduling of combine harvester (http://easyharvest.irri.org/)
- Rice Doctor, a diagnostics tool to help you to identify pest and disease problems in your crop and provide actionable advice how to manage them. (http://www.knowledgebank.irri.org/decision-tools/rice-doctor)

APPENDIX: COMMON NATURAL ENEMIES

This section provides photogrpahs of natural enemies of rice insect pests. These predators need to be protected. *(Source: Shepard et al., 2000).*

1. Predators predators

Adult and dark larva of *Micraspis* sp. feeding on nymphs of brown planthopper (http://rkb.irri.org.)

8-spot lady beetle
Harmonia octomaculata

Rove beetle
Paederus fuscipes

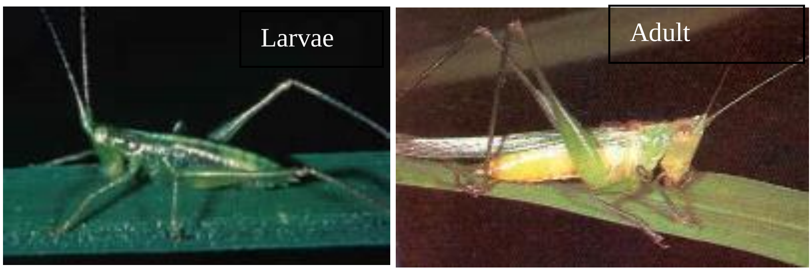
Ground beetle
Ophionea nigrofasciata

Mirid bug
Cyrtohinus lividipennis

Water bug
Microvelia douhlasi

Water bug
Mesovelia vittigera

Water strider
Limnogonus fossarum



Meadow grasshopper
Conocephalus longgipennis

Damslflies
Agriocnemis femina femina

Sword-tailed cricket
Metioche vittaticollis

Earwig
Euborellia Stali

2. Spiders – predators of insect pests of rice

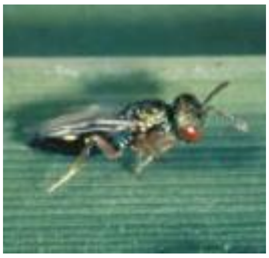
Wolf spider
Lycosa pseudoannulata
feeding on rice stem

Orb spider
Argiope catenulate

Long-jawed spider
Tetragnatha maxillosa

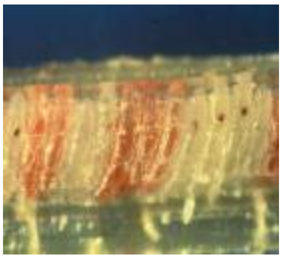
3. Parasitoids

3.1. Hopper egg parasitoids



Ong mắt đỏ
Trichomalopsis panteloctena

A fairyfly
Anagrus optabilis



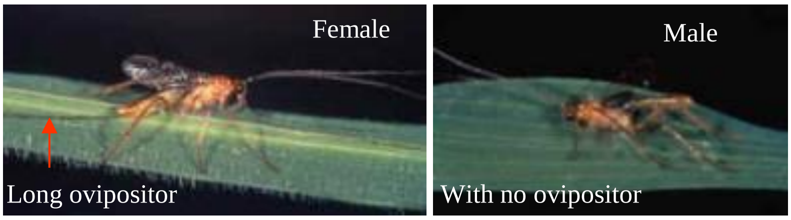
Hopper eggs parasitised by *Anagrus* spp. turn deep orange red

Oligosita naias

Hopper eggs parasitised by *O.naias*

Gonatocerus spp.

3.2 Parasites of leaffolder and stem borer larvae



Medium-sized braconid wasp
Macrocentrus philippinensis

Newly emerged black braconid wasps, *Cotesia angustibasis*

Dead leaffolder larva with white cocoons of a *C. angustibasis*

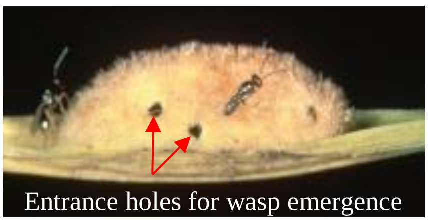
Yellow-orange wasp
Xanthopimpla flavolineata

Yellowish orange ichneumonid wasp
Temelucha philippinensis

Ichneumon wasp
Charops brachypterum

Black&white cocoon of Ichneumon wasp

Metallic pteromalid wasp
Trichomalopsis apanteloctena



Adults of Scelionid wasp, *Telenomus rowani* parasitizing an egg mass of stem borer

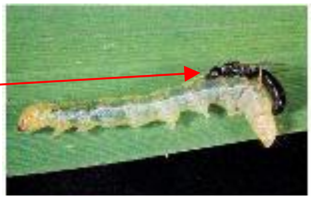
Ichneumon wasp,
Amauromorpha accepta metathoracica

Braconid wasp,
Cardiochiles philippinensis

Chalcidid wasp,
Brachymeria lasus

Chalcid wasp,
Brachymeria excarinata

Bethylid wasp,
Goniozus nr. triangulifer

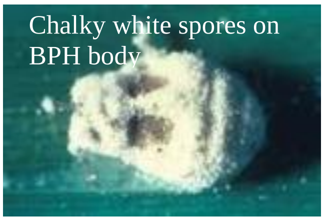


A wasp paralyzing the
leaffolder before laying eggs

3.3 Fungus

A rice hopper parasited
by *Metarhizium*
flavoviride

A rice hopper parasited by
Hirsutella citriformis



A brown planthopper
parasited by *Beauveria*

A rice leaffolder larva
parasited by *Nomuraea*

An infected larva by *Nuclear*
polyhedrosis virus

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