TropRice

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Overview

Features

TropRice is an information support system to help you make more informed practical decisions related to tropical rice production.

What is TropRice?
TropRice is a DRAFT information system of best practices designed to provide practical field level guides for rice crop management in the Tropics.

What TropRice isn't
TropRice is NOT a single system for the world. While some information is generic, other information is site- or region-specific. TropRice is meant to be a template to be modified for different environments. The present system is aimed at irrigated rice in a Los Baños-type environment. As improved systems on component technologies become available, they will replace or be linked to this system. Collaborators should modify this system for their particular environments.

Who developed and contributed?
TropRice lists the many IRRI scientists who have contributed to the technical content. TropRice is a project under development. As such, the list of contributors is growing.

Who is the target?
TropRice is aimed at intermediary technology transfer agents

Complexity
TropRice aims to be simple.

Why was it developed?
TropRice was developed in response to the recognition that many farmers do not have access to information on how to grow their rice. Information technology offers new ways to package and present information.

Evaluation to date
Three separate groups (including NGOs, farmers, and private and public sector) have provided early feedback. Your evaluation is appreciated.

What can you do?
Please evaluate TropRice and provide suggestions and comments regarding content, layout, errors, and ease of use. If you would like to collaborate on "localizing" TropRice for your conditions or have any comments, questions, or suggestions, please contact Dr. Mark Bell at **M.Bell@CGIAR.ORG**.

Thank-you for your assistance.

Software & Hardware Requirements

Browser

TropRice is best viewed with Internet Explorer, version 4 or higher. If your computer is capable of running this browser, you will be able to use TropRice without any additions or modifications.

Links

University of Arkansas Rice Page

University of California at Davis

Louisiana State University

University of Missouri

Mississippi State Extension Service

Texas A&M University

Contributors

Role	Contributor
Project leader	Mark Bell
Design & programming	Albert Dean Atkinson
Preliminary design and programming	Carrie Chung, Jamie Gray, Shah Faisal
Product pre-testing	E. Razote
Post -production	R. Bakker
Nutrient management	V. Balasubramanian
Weed management	Kate Barnard, J. Hill, K. Moody, M. Mortimer
Variety x Nutrient management, crop management	K. Cassman, S. Peng
Agricultural Engineering	J. Rickman
Nutrient management	A Dobermann, V Balasubramanian
Insect management, Integrated pest management	K.L. Heong
Variety	G. Khush
Seed quality	T. Mew
CREMNET	A. Morales
Land preparation, Crop establishment	J. Rickman
Water Management	T.P. Tuong
Graphics	Eugene Castro, CONNEX

Updates

While the whole of TropRice has been reviewed and reformatted, the following sections have had major changes and new sections added:

- Nutrient Management
  LCC section - **Cost and where available**

- Nutrient Management

- Weed Management

- Insect Management

- Integrated control measures for rice pests

- Disease Management
  Product Calculator

- Byproduct uses

- Post-production

- Economics
  Economic Calculator

Disclaimer

To the best of our knowledge the material presented here is correct. However, IRRI and the authors are in no way responsible for the application, etc. of the methods or information mentioned. They make no warranties, expressed or implied, as to the accuracy or adequacy of any of the information presented.

The material is presented for information only and no endorsement is intended for products listed, nor criticism meant for products not mentioned. In the case of agrochemicals, always consult the product label and the accompanying instructions before purchasing and using any product.

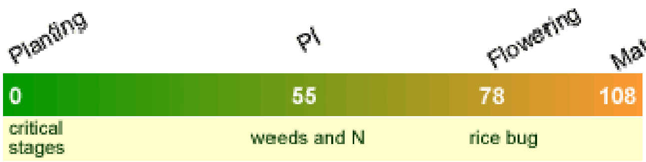
Management Timetable

Wet Direct Seeded Timetable

NOTE: This example management timetable is for an early variety (e.g., IR72 - 108 days to maturity) - the timetable will need to be adjusted based on expected maturity of variety.

Numbers refer to days relative to days after seeding (DAS)

Development of IR72



- Panicle initiation (PI) 55 DAS
- Flowering 78 DAS
- Maturity 108 DAS

Pre-plant management

DAS	Recommendation
-2 to -3	• Final land preparation (make sure field is **level**; allow time for soil to settle before planting - or seed may sink too deep to emerge) • Basal fertilizer can be applied, or apply fertilizer (e.g., 30:30:30) 7-10 Days after seeding
-2	• Soak seed USE **CLEAN SEED** (to increase plant vigor and reduce disease and weeds).
-1	• Incubate (drain) seed • Install canalettes to drain low spots of field (to reduce snail damage and seed sinking) if not done during final land preparation.

Crop establishment

DAS	Recommendation
0	• Broadcast seed (suggested rate 60-120 kg/ha) or aerobically seed (60-80 kg/ha). (It is better to have the seed slightly covered to reduce losses to birds and rats - however, too deep and the seed will have problems in emerging). • Do not plant too deep (plant <0.5 cm).

Weed Management
NOTE: If used, the timing of herbicide application is very important relevant to the last land preparation activity.

DAS	Recommendation
0 to +1	• Use good fallow management (keep weeds from seeding), land preparation, **land leveling**, and **water management** significantly reduce weed pressure. • Apply pre-rice germination products such as: **Butachlor** (Machete), Preticlachor (**Sofit**), or Oxidiazon (**Ronstar**), or **Oxyfluoren** (Goal)
0 to 20	• Manual weed - most critical time.
-1 to +20	• Apply pre-rice germination to tiller initiation - **Thiobencarb** (Saturn or Thiobencarb-D - with 2,4-D), or manually control weeds.
+20 to +52	• Apply around tiller initiation to pre-panicle intiation - **2,4-D** (Various names - e.g., Esteron), **MCPA**, **Bentazon** (Basagran), **Propanil** (Advance - mixed with butachlor). Click for detailed **product information** along with specific field management information.

Water Management

DAS	Recommendation
0 to +21	• Flash flood (to reduce snail damage).
+40 to +45	• If required, irrigation can be withheld (to reduce excess tiller production).
+95 to +100	• Drain field (to facilitate maturation and mechnical harvest).

Nutrient Management

DAS	Recommendation
0 to +52	• (panicle initiation) If apply basal N, then apply N as required if plant stand and tiller number low (may need around 45 kg N/ha at 20-30 DAS) **Calendar N management LCC** and **Spad meter** use
+49 to +52	• CRITICAL - Monitor N status - apply around 45 kg N/ha if needed - N nutrition at panicle initiation must be adequate (to ensure adequate sink size)

Insect and Disease Management

DAS	Recommendation
Mid tillering & on	• Scout for **Tungro** (stunted orange plants - rogue if found. **IPM** - monitor crops for primary pests) - transmitted by **green leafhopper**.
+40 to +65	• Control **stemborers** if thought necessary (causing whiteheads) - a prophylactic application may be required - monitoring measures are somewhat inadequate.
+65 to Milk stage	• Monitor **Rice bugs** - if greater 1 bug/hill at milk stage apply control.

Post Production

NOTE: Harvest at around 20-25% MC for best quality grain.

DAS	Recommendation
+95 to+100	• Drain field at around 7-10 days before physiological maturity - around 20-23 days after flowering for IR 72 types.

Drying: use ambient air if relative humidity <70% - use the blower during the day (as relative humidly is higher during cooler nighttime and morning times), else dry at 43 degrees C.

Photos
Wet direct seeded (WDS) field: Seed is planted into field prepared while saturated.

WDS requires good leveling and weed control. WDS fields can have problems of seed loss (rats and birds), snails, emergence, lodging, and weeds. Fields can be broadcast or sown in rows. Typically, 1-4 ha can be planted per day.

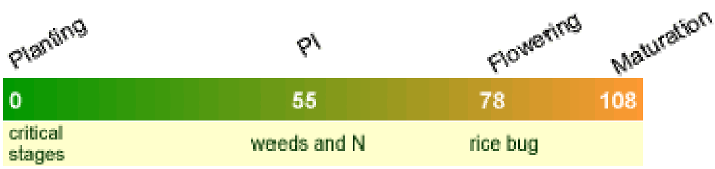
Dry Direct Seeded Timetable

NOTE: This example management timetable is for an early variety (e.g., IR72 - 108 days to maturity) - the timetable will need to be adjusted based on expected maturity of variety.

Numbers refer to days relative to days after seeding (DAS)

- Weed pressure is generally much higher under dry seeded crops - In addition, presently there are fewer herbicide options.
- Water and Nitrogen use may be higher (especially early in the season) depending upon soil texture and infiltration characteristics (especially where puddling would generally be required to reduce infiltration rates)

Development of IR72



- Panicle initiation (PI) 55 DAS
- Flowering 78 DAS
- Maturity 108 DAS

Pre-plant management

DAS	Recommendation
-2 to -3	• Final land preparation (make sure field is **level**. • Basal fertilizer can be applied, or apply fertilizer (e.g., 30:30:30) 7-10 Days after seeding. • Install canalettes to drain low spots of field (to reduce snail damage in low spots) if not done during final land preparation.

Seed priming - work in India has found that rice can be soaked (24 hours) and then re-dried. Upon planting, it has quicker emergence.

Crop Establishment

DAS	Recommendation
0	• Plant seed (suggested rate 60-120 kg/ha). • Broadcast (80->120 kg/ha) and harrow if possible (to reduce losses to birds and rats). • Broadcast into 15 cm spaced furrows and cover (80-120 kg/ha). • Drill seed (60-100 kg/ha.) • USE **CLEAN SEED** (to increase plant vigor and reduce disease and weeds.) • Do not plant too deep (plant <0.5 cm).
+1	• Incubate additional seed (e.g., 1 kg/0.25 ha) to use to fill in any gaps during crop emergence. NOTE: Some herbicides (**propanil**), if

	applied before resowing, may kill the new seed.
+15 to +20	• Fill gaps by transplanting if not filled by re-seeding. • Reduce pest damage during crop establishment - **snails, rats and birds**.

Weed Management
NOTE: If used, the timing of herbicide application is very important relevant to the last land preparation activity.

DAS	Recommendation
0 to +1	• Use good fallow management (keep weeds from seeding), land preparation, land leveling, and water management significantly reduce weed pressure. • Apply pre-rice germination products such as: **Butachlor** (Machete), Preticlachor (**Sofit**), or Oxidiazon (**Ronstar**), or **Oxyfluoren** (Goal)
0 to 20	• Manual weed - most critical time.
-1 to +20	• Apply pre-rice germination to tiller initiation - **Thiobencarb** (Saturn or Thiobencarb-D - with 2,4-D), or manually control weeds.
+20 to +52	• Apply around tiller initiation to pre-panicle intiation - **2,4-D** (Various names - e.g., Esteron), **MCPA**, **Bentazon** (Basagran), **Propanil** (Advance - mixed with butachlor). Click for detailed **product information** along with specific field management information.

Water Management

DAS	Recommendation
0 to +21	• Flash flood (to reduce snail damage)

+40 to +45	• If required, irrigation can be withheld (to reduce excess tiller production)
+95 to +100	• Drain field (to facilitate maturation and mechnical harvest)

Nutrient Management

DAS	Recommendation
0 to +52	Apply N as required (may need around 45 kg N/ha at 20-30 DAS)
+49 to +52	CRITICAL - Monitor N status - apply around 45 kg N/ha if needed - N nutrition at panicle initiation must be adequate (to ensure adequate sink size)

Insect and Disease Management

DAS	Recommendation
Mid tillering & on	• Scout for **Tungro** (stunted orange plants - rogue if found. **IPM** - monitor crops for primary pests) - transmitted by **green leafhopper**.
+40 to +65	• Control **stemborers** if thought necessary (causing whiteheads) - a prophylactic application may be required - monitoring measures are somewhat inadequate.
+65 to Milk stage	Monitor **Rice bugs** - if greater 1 bug/hill at milk stage apply control.

Post Production
Note: Harvest at around 20-25% MC for best quality grain.

DAS	Recommendation
+95 to+100	• Drain field at around 7-10 days before physiological maturity - around 20-23 days after flowering for IR 72 types.

Drying: use ambient air if relative humidity <70% - use the blower during the day (as relative humidly is higher during cooler nighttime and morning times), else dry at 43 degrees C.

Photos:

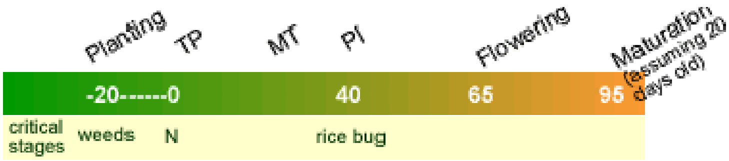
Dry direct seeded (DDS) field: Seed is usually planted into a field prepared while dry or moist. DDS requires good leveling and weed control.

Transplanted Timetable

NOTE: This example management timetable is for an early variety (e.g., IR72 - 108 days to maturity) - the timetable will need to be adjusted based on expected maturity of variety.

Numbers refer to days relative to days after transplanting (DAT)

Development of IR72



- Panicle initiation (PI) 40 DAT
- Flowering 65 DAT
- Maturity 95 DAT

Pre-plant management - Nursery and Seedling

DAT (Days After Transplanting)	Recommendation
-28	• prepare nursery • USE **CLEAN SEEDS** (to increase plant vigor and reduce disease and weeds)
-28 & -27	• Soak and incubate seeds
-26	• Plant nursery
Land Preparation	
-2 to -3	• Final land preparation (make sure field is level; allow time for puddled soil to settle before planting - or plants may fall over). • Apply basal fertilizer (e.g., 30:30:30) during final land preparation. • Initial N can be delayed to around 10 DAT
-1	• Install canalettes, if possible, to allow subsequent drainage of low spots of field (to reduce possible snail damage and promote drainage to facilitate mechanical harvest)

Crop Establishment

DAT	Recommendation
0	• Transplant (suggested spacing 20 cm x 20 cm for manual; 30 cm x 12 cm for mechanized transplanting)
+7 to +15	• Fill gaps by transplanting.

Weed Management

NOTE: If used, the timing of herbicide application is very important relevant to the last land preparation activity.

DAT	Recommendation
-1 to 0	• Use good fallow management (keep weeds from seeding), land preparation, land leveling, and water management significantly reduce weed pressure. • Pre-transplanting - Thiobencarb or pretilachlor
0 to +1	• Butachlor (Machete), Preticlachor (**Sofit**), or Oxidiazon (**Ronstar**), or **Oxyfluoren** (Goal)
-1 to +20	• Apply pre-rice germination to tiller initiation - **Thiobencarb** (Saturn or Thiobencarb-D - with 2,4-D), or manually control weeds.
+20 to +40	• Apply around tiller initiation to pre-panicle intiation - **2,4-D** (Various names - e.g., Esteron), **MCPA**, **Bentazon** (Basagran), **Propanil** (Advance - mixed with butachlor).

Water Management

DAT	Recommendation
0 to +15	• Flash flood (to reduce snail damage).
+20 to +25	• If required, irrigation can be withheld (to reduce excess tiller production).
+81 to +88	• Drain field (to facilitate maturation and mechanical

	harvest).

Nutrient Management

DAT	Recommendation
0-+40	Apply N as required if plant stand and tiller number low (may need around 45 kg N/ha at 18-21 DAT).
Panicle initiation +35 to +38	CRITICAL - Monitor N status - apply around 45 kg N/ha if needed - N nutrition at panicle initiation must be adequate (to ensure adequate sink size).

Insect and Disease Management

DAT	Recommendation
Mid tillering & on	Scout for **Tungro** (stunted orange plants - rogue if found. **IPM** - monitor crops for primary pests) - transmitted by **green leafhopper**.
+40 to +65	Control stemborers if thought necessary (causing whiteheads) - a prophylactic application is required - monitoring measures are somewhat inadequate.
+65 - Milk stage	Monitor Rice bugs - if greater 1 bug/hill at milk stage apply control.

Post Production
Note: Harvest at around 20-25% MC for best quality grain.

DAS	Recommendation
+95 to+100	• Drain field at around 7-10 days before physiological maturity - around 20-23 days after flowering for IR 72 types.

Drying: use ambient air if relative humidity <70% - use the blower during the day (as relative humidly is higher during cooler nighttime and morning times), else dry at 43 degrees C.

Photos:
Transplanted (TP) field: Your seedlings are planted into a field prepared while saturated. TP fields can have problems of snails. Hand TP requires 15-20 person days per ha. Mechanical TP can plant 1-2 ha per day.

Land Preparation

Principles of Land Preparation

Land preparation is the key to good crop establishment. Due to the diversity of systems, we simply present some key principles here for consideration.

Typical comparison of tillage systems and time required:

System	hrs/ha
Animal	120-135
Hand tractor	40-60
4 Wheel tractor	5-10

- **Benefits**: More timely land preparation can ensure planting at a more optimal time.
- **Water management**: Mobility and tillage depth depend largely on water management. If the soil is kept wet and soft, then all equipment— especially larger equipment—will tend to sink, creating problems of mobility and tillage depth. When tillage layers are too deep then subsequent operations such as walking, hand tractor passes, or combine harvesting can have problems.
- **Weeds**: Tillage can reduce weed burdens e.g., till on moist soil and re-till after two weeks just prior to planting to kill germinating weeds.
- **Land leveling**: Keep and improve land level.
- **Residue breakdown**: Soil does not have to be saturated for residue to break down. Residue decomposition is best at soil moisture levels of a moist but well drained field (i.e., less than field capacity) and at soil temperatures of 25° and greater.
- **Breakdowns**: Animals get sick, but machinery breaks down. When shifting to machinery, ensure proper use, spare parts and after-sales services are available.

Photos:
Land preparation by animal takes around 120-135 hours per ha.

Land preparation by hand tractors takes around 40-60 hours per ha.

Land preparation by large tractors takes around 5-10 hours per ha.

Principles of Zero-Tillage

The section on safe applications highlights a number of key principles involved in zero-tillage.

Although different names are used (e.g., minimum tillage, direct seeding, etc.) zero-tillage refers to a system of crop production where the soil is not traditionally tilled. Instead of tillage, the seed is planted directly into the soil and special planting equipment is usually required. Most commonly the seeders require 4 wheel tractors, although the seed can be dibbled in by hand (often using sticks to make the opening), or some small equipment suitable for animals or hand tractors can be used.

Soil moisture and texture become important for determining when a soil can be planted.

Widely used for various crops such as wheat and maize, the system is also widely used for rice in Brazil and in other countries such as Panama, Costa Rica, Nicaragua, Guatemala, Dominican Republic and Colombia.

The system relies on retaining surface residue that reduces evaporation and limits weed growth. The soil typically increases in bulk density, but porosity increases which improves water infiltration.

General Equipment Use Considerations

- Maintenance: Check and tighten bolts, grease high friction parts about every 8 hours of operation.
- Operating speed: For tractors, operate near full throttle. Many operations can be performed around 7-8 km/hr. If rpm drop by more than 10% upon engagement of equipment, then use a lower gear.

Primary Tillage Options

Ploughs (Mouldboard, Disc, Tine, Offset)

Primary tillage is the first operation to prepare the soil for planting. Mouldboard ploughs fully invert the soil:

Disk ploughs partially invert the soil:

Tine ploughs loosen the soil without inverting the soil:

Offset ploughs partially invert the soil:

Objectives:

- Work soil 10-15cm (4-6") deep
- Open soil for drying
- Chop straw
- Bury straw
- Kill weeds
- Rough surface for water retention

Key points:

- Engine power requirements of the order 14-26 kW/m at 7.2 km/hr
- Stabilizer chains should be relatively loose (but not so loose that implement hits tires)
- Plough should be level in two planes (front to back, side to side)

- If the tractor is "pulling" to one side, then the plough is not properly adjusted
- Depth of cut should be uniform - results if plough is level
- Field should be as level as possible after ploughing (no ridges)

Disc Harrow and Offset Disc

1. Tandem disk - Two sets of gangs front and rear in the shape of an "X". Front disks face outward (and throw soil outward)- back disks face inward.

2. Offset disk - Single front gang with single rear gang. Concave face of gang disks face opposite directions:

Objectives:

Under wet (saturated) conditions:
- Work soil 10-15 cm (4-6") deep.
- Break down roots.
- Soften ground for subsequent puddler operation.
- Chop straw.
- Incorporate straw.
- Kill weeds.

Key points:
- Engine power requirements of the order 14-18 kW/m at 7.2 km/hr
- Stabilizer chains should be relatively loose (but not so loose that implement hits tires).
- Level in two planes (front to back, side to side).
- Main adjustment is top hitch.
- As the angle of a harrow is increased, the depth of cut and force increase.
- Front angle of disks is generally about 20°, and the back disks slightly greater.
- Front disk blades wear faster than following blades.
- Have bumper pads between center disks (to stop disks from knocking).
- Cut to a maximum of 1/4 of the disk diameter.
- Should leave a relatively flat surface - a depression or ridge in the middle of a tandem disk harrow indicates that disk spacing, working speed or top link of the three point hitch need adjustment.

- **BEWARE:** Disk cut should not overlap (i.e., back disks cut should be between front disk cut). Don't cut deeper than 1/4 of disk diameter.

Rotovator

Rotovation is usually a secondary or finishing tillage operation to bury weeds and trash and prepare the bed for planting:

Objectives
- Develop suitable tilth for seed germination/planting.
- Kill weeds.
- Incorporate straw/weeds.
- Puddling soil.

Use of rotavators should be limited as they: 1) use a lot of energy relative to other land preparation equipment, and 2) involve a lot of moving parts so maintenance costs are higher. Often used for nursery seedbed.

Key points
- Engine power requirements of the order 20-35 kW/m at 7.2 km/hr.
- PTO shaft turns at 540 rpm.
- PTO shaft should overlap by 10-15 cm.
- PTO shaft should be horizontal to the ground when the rotovator is lowered and in use.
- Blade depth - the maximum cut should be approximately 1/3 of diameter.

- **BEWARE:** In dry fields, you should NOT turn in the field with rotavator down.

Puddler

Puddling completely breaks down soil structure to decrease water percolation and to bury weeds. It loosens soil for greater ease of leveling. Rotovators can be used for puddling:

Objectives

- Decrease weeds.
- Decrease percolation as a result of soil dispersion.
- Level the soil for better planting conditions and/or for snail control. (where a problem).

Key points

- Engine power requirements of the order 7 kW/m at 7.2 km/hr (see Table 2).
- Puddlers should be used only when necessary for snail and water management.

Note: Rotopuddlers (e.g., those used at IRRI) can be used with a "Laser" guided system.

Rotopuddler with laser guided system.

Land Plane

Objective

- Smooth land surface (not level!).

Key points

- A land plane will require up to 28 engine kW/m.
- Should run at about 1/2 full (in practice, it may run empty 10-15% of the time).
- The soil aggregate size should be less than the height of the cut.
- The cut will often be about 1 inch.

Land Leveling

Why Level? Benefits and Principles

Benefits: Land leveling improves water management which improves:

- Weed suppression and control
- Crop establishment
- Nutrient use efficiency
- Crop uniformity and maturation
- Drainage (and thus mobility)
- Yields
- Profits

Note: The benefits of land leveling are greater with more uneven land, but cost increases with the amount of soil to move.

Objective
Farmers' production fields should look as level and well prepared as their seedling nurseries.

Principles of land leveling

- Maintain level: Must have good tillage practices to maintain soil level and protect investment.
- Returns: Benefit should be seen over more than one year.
- Fertilizer & cut areas: Cut areas require additional nutrition. In some areas, chicken manure, if available, is applied at a rate of 1-2 t/ha. Otherwise a compound fertilizer (especially N & P) can be applied at around (1-2 bags/ha).
- Subsoil considerations: Although heavy cuts (e.g., > 1 m) can be and often are made, it is important to make sure that the exposed sub-soil will not be problematic (e.g., acidity, salinity, sodicity, higher percolation rate, etc.)
- Efficiency: Minimize soil movement by identifying highs and lows.
- Efficient land leveling requires good operator skill.

Topographical Survey

A grid survey to identify highs and lows is required. A grid spacing of 20 m x 20 m is often adequate, although 10 m x 10 m will be more accurate. For practical purposes and with experience, grid surveys can be done by pacing off the distances (rather than measuring). A map is then drawn to indicate which areas are high (and require soil to be cut) and the lows which require soil to be added.

The areas of highs and lows (cut and fill) can be marked in the field by using different colour pegs or cloth attached to pegs.

Note: With a lot of experience, laser leveling operators can actually drive in to a field - drive a figure 8 over the field from each of two corners - identify the high and low spots and begin leveling without a survey.

Photos:
Field surveying is used to generate maps to identify high and low areas in the field:

Field ready to plant:

Equipment and Steps in Leveling

Land preparation

1. Remove stubble and dry plough the field - Chisel and 7 bottom disk ploughs are very suitable for the ploughing. If fields are very hard a 3 disc plough may be needed. In any ploughing operation care needs to be taken to leave the field as level as possible - See **Tillage practices to maintain a level field**.
2. Shifting soil.
3. Animals and hand tractors - use in range 0 to 0.25 ha:
    - Hand tractors plus a blade and animals and harrows can level areas up to 0.25 ha. These systems are capable of removing 4-5 cm variability from a field. Animals require up to 12 working days per ha and walking tractors up to 8 days per ha. Fields will need to be ploughed and flooded to ease soil movement. Care needs to be taken using walking tractors so as to avoid excessive wheelslip and subsequent bogging of the tractor and implement.

    - 4 Wheel tractors + blades - use in range 0 to 0.5 ha:
        - A back blade can be used in both wet and dry conditions.
        - If dry, the bucket should have wings attached to the ends of the blade (to reduce soil loss around the ends of the blade) and a depth control wheel at the back. Field operations should be planned to not drag soil more than 25-30m in any one pass.
        - If wet, the blade should have no wings or depth wheel.
        - Front blades should only be used for dry leveling and require more operator skill to attain a satisfactory result.

    - Drag buckets are more efficient and faster than 3 point hitch blades and leveling buckets.

Tractor and scraper size

Tractor size Min/Max (HP)	Scraper width Min/Max (m)
30-50	2
50-100	2-3
100-125	3-3.5
125-150	3.5-4
>150	4-5.5

- 4 Wheel tractors + Bucket - use in range > 0.1 ha
- Drag buckets are more efficient and faster than 3 point hitch blades and leveling buckets
- Laser systems - Both buckets and blades can be mounted with laser systems that automatically control the height of the bucket or scraper.

4. Time required and suitability:

Method	Per day	Accuracy	Area (ha)
Animal	0.08	+/- 4-5 cm	0-0.25
Hand tractor	0.12	+/- 4-5 cm	0-0.25
Blade	0.5-1.0	+/- 4-5 cm	0-0.5
Bucket	0.5-1.0	+/- 4-5 cm	>0.1
Laser	up to 2 ha	+/- 1cm	>0.1

Note: Capacity depends on size, residue, shape, moisture, soil type, soil condition (ped size) and the skill of the operator.

Pattern of soil movement in field

Identify the high spots and the low spots. The objective is to minimize soil and equipment movement. Therefore, calculate how to reduce the amount of travel between the highs and the lows. *With experience* - By driving a figure eight over the length and breadth of field, you can identify the high and low spots and estimate the most efficient manner to move soil.

Photos:
Ploughed soils can be moved under dry

or wet conditions. More soil can be moved when dry.

Desirable Field Size and Shape

Under present Asian conditions, a desirable shape is 2 to 1 (e.g., 100m x 50 m or 0.5 ha). In countries such as the USA and Australia, fields may be leveled up to 4 ha or more. For ease of future management it may pay to shift a little more soil than would otherwise be necessary to end up with straight sided rectangular fields.

Considerations in Leveling

1. **Slope** - For Asian conditions, 0% slope is best. The field should have a drain around the outside to facilitate water management, and small canals (e.g., 10-15 cm deep) from the middle of the field to the drainage points. (Note: In the USA and Australia, most fields, which are larger are sloped to allow quicker drainage of water to facilitate operations such as combine harvesting

or subsequent crop rotations.)

2. **Infiltration** - It is important to be aware of the physical properties such as infiltration rates of the subsoil. In areas where a large amount of soil is moved and hard pans are removed, excessively high infiltration rates may lead to increased rates of nutrient and chemical leaching. Sub-soil properties (infiltration rates should be checked before doing deep cuts). Infiltration rates should at least match that of the surface soil. Infiltration can be estimated using double ring infiltrometers - or by building a small bund, adding water at a constant rate and checking either rate of water loss or time to ponding.

3. **Cost** - The cost depends in large part on the amount of soil to be moved. Actual costs should run around US$3-5/cm of soil variability removed or $40-60/ha.

4. **Fertility** - *"Cut"* areas may be less fertile as the soil organic matter and the richer top soil is removed to the *"fill"* areas. Chicken manure applied at 1 to 2 t/ha or a mixed fertilizer like di-ammonium phosphate (DAP - 18:20:0:3 - N:P:K:S) applied at 1 bag per ha to the cut areas prior to, or at planting will typically help with such problems. The crop should be used as an indicator for additional fertiliser requirements.

   Fill areas may lodge and require less fertilizer in the first crop as the richer soil from other parts of the field is moved to these areas.

Bund/Levee Building and Drainage

Bunds - Bunds retain water. High bunds are often an indication of poorly leveled fields. Bunds can be built manually or mechanically and are an important component of good water management. Leveling typically reduces both the number and size of bunds, thus increasing the cropped area. New bunds will require compacting and additional filling after initial settlement occurs It is always best to build or at least mark out the bunds before leveling commences. If a mechanical bund builder is used run over the bunds with the tractor tyre after finishing the leveling operation to compact the bund.

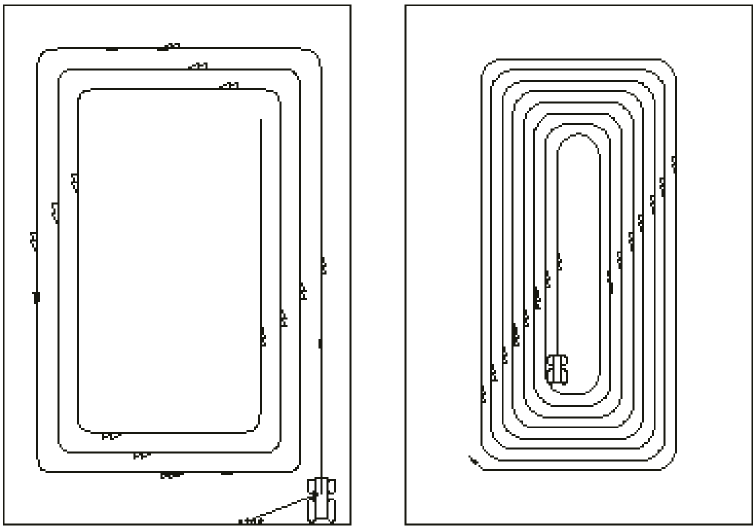
Drainage - The field should have a drain around the outside to facilitate water management, and small canals (e.g., 10-15 cm deep) run from the middle of the field to the drainage points. As the drain will be lower than the field surface drainage direction is easily controlled.

Tillage Practices to Maintain a Level Field

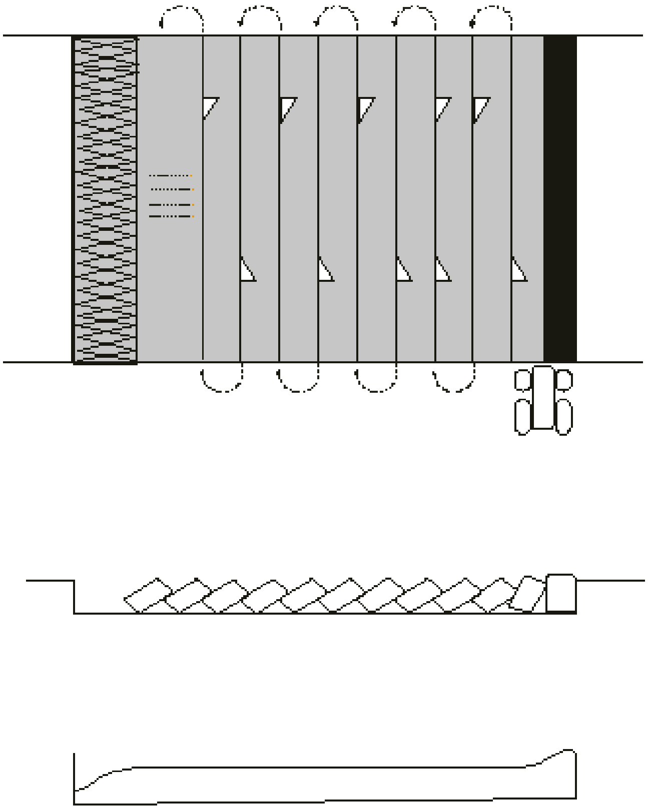
Traditional tillage practices have often moved the soil in one direction—outward from the center of the field. Over time, such soil movement will create an uneven soil surface (a saucer or a dish effect) resulting in a low spot in the centre of the field. The center of the field will often be wetter and tillage operations will often be delayed and the incidence of weeds increased.

After leveling, fields should be ploughed in "lands". This requires the ploughing operation to begin in the centre of the field and working out toward the field boundary. Initially a single pass should be made in the centre of the field to move the soil to the right. The tractor is then re-positioned at the end of the first run so as to plough the second run outwards from the furrow created. The third plough run then moves the previous ploughed soil back into the depression in the centre of the field.

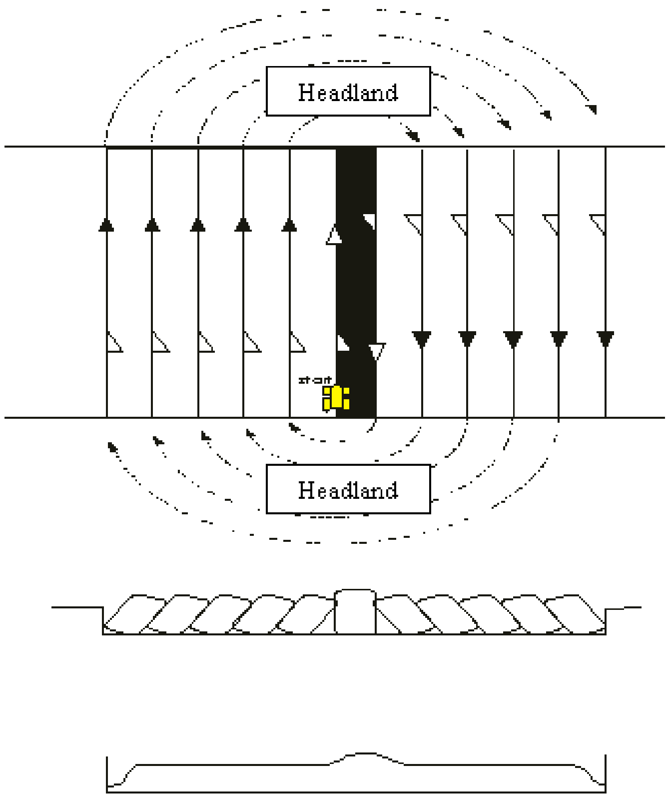
The fourth run then refills the remaining furrow leaving the centre of the field level. The field should then be ploughed up and back either side of the land until a margin equal to the same width of the headland is left. The remainder of the field is then ploughed in a continuous pattern with the final run leaving a drainage furrow beside the bund.



Circuitous Pattern



Headland Pattern



Land System Pattern

IRRI Rice Varieties

IRRI Rice Varieties Table

Scan the tables to find the maturity class for your variety

Variety selection - Broad principle: Choose a variety based on:

- Seed health - Clean seed can increase yields
- Disease and insect resistance
- maturity (mature to avoid adverse conditions)
- Quality that the market wants
- Tillering capacity

Maturity class	Days from TP *assuming 20 day old seedlings*	Days from direct seeding
Very early	90	103
Early	95	108
Medium	110	123

NOTE: For transplanted crops - 20 day old seedlings - subtract 7 days for development stages under direct seeding as plants mature quicker (e.g., Early = 95 + 20 - 7 = 108).

Table Key: DTF-Days to Flowering, DTM-Days to Maturity, MR-Moderately Resistant, s-Susceptible, R-Resistant, GLH-Green leafhopper, GPH-Green planthopper

Variety	Maturity class	DTF	DTM	Blast	Sheath blight	Tungro	GLH	BPH	stem borer
IR5	Late	107	134	MR		S	R	S	MR
IR8	late	98	126	S		S	R	S	S
IR20	Late	93	121	MR		S	R	S	MR
IR22	Medium	91	120	S		S	S	S	S
IR24	Medium	92	122	S		S	R	S	S
IR26	Medium	92	122	R		R	R	R	MR
IR28	Very early	76	105	R		R	R	R	MR
IR32	Med-Late	107	115	MR		R	R	R	MR
IR36	Very early	80	109	MR		R	R	R	MR
IR38	Early-Medium	91	120	MR		R	R	R	MR
IR42	Medium	103	132	R		R	R	R	MR
IR46	Medium	95	121	MR		R	R	R	MR
IR50	V. Early	78	107	S		R	R	R	S
IR54	Early-Med	95	123	MR		R	R	R	MR
IR58	Very early	74	104	MR		R	R	R	S
IR60	Early	81	109	MR		R	R	R	MR
IR62	Early-Medium	88	117	MR		R	R	R	MR

IR64	Early	87	116	MR		R	R	R	MR
IR66	Very early	85	114	MR		R	R	R	MR
IR68	Early-Medium	96	125	MR		R	R	R	MR
IR72	Early	86	119	MR		R	R	R	MR
IR74	Medium	74	129	MR		R	R	R	MR
PSBRC2	Medium	98	129						
PSBRC4	Very early	77	108						
PSBRC10	Very early	76	108						
PSBRC18	Medium	95	129						
PSBRC20	Early	80	113						

Crop Establishment

Overview of Crop Establishment

This section on crop establishment assists farmers with decisions related to the sowing of the rice crop. Information on how to plant or seed (pre-germination, seeding depth, broadcasting, etc.) is provided for wet direct, dry direct and transplanted forms of crop establishment. Critical factors related to crop uniformity are also included along with how to control the major pests that appear during this time. Additional information regarding target plant stands, seed rates and replanting (to fill leftover gaps in the field) has also been provided.

Principles of Crop Establishment

- General goal: Establish a uniform plant stand.
- Transplanting gives a more uniform stand.
- Direct seeding, especially wet direct seeding, can be problematic.
- If direct seed then:
    - need more uniform land leveling and better water management.
    - seed planted too deep results in poor emergence and weak plants.
    - seed planted too shallow is susceptible to bird and rat attack.
    - Soil strength - For wet direct seeding, if the soil holds a shape after a stick is dragged through the mud, then the seed will not sink too deep. If the shape freely collapses, then the seed will likely sink too deep and have problems emerging.

- **Lodging** can be reduced by transplanting (especially in the wet season and direct seeding below the surface during the dry season), choice of variety, limiting N applications between PI and flowering, and reducing stem base diseases.
- Critical panicle numbers - For IRRI conditions, maximum yields require 500-600 panicles/m2 in the dry season and 350-400 panicles/m2 in the wet season for IR 72-type varieties.
- The following tables summarize the principal considerations in moving from transplanting to direct seeding.

Wet Direct Seeded

Use **CLEAN SEED** - and increase yields by 5-20%!

Major issues for wet direct seeded crops are:

- Seed germination and emergence - Seed buried under mud or under mud and water has difficulty emerging.
- Weed control.
- **Land leveling** and early water management, and
- **Pests during crop establishment**
- Pre-germinate seed
    - 48 hours before planting soak seed - change water every four hours if possible.
    - After 24 hours, incubate seed in the shade - rinse if possible to avoid seed becoming too hot.

- **Wet/Dry seeding comparison**.

Seeding depth

- Target planting depth - <1cm If drilled - 0.5 cm (maximum 1 cm - Variety dependent).
- Surface seeding has fewer emergence problems than buried seed, but may have problems of **birds and rats**.

Soil tilth

- Rule of thumb - the soil is ready for planting if a "V" made by dragging a stick through the prepared soil holds it's shape. If the soil is too wet, the "V" will collapse indicating the seed will likely sink too deep and have problems of emergence.

Seeding

- Wait 1-2 days after land preparation (depending on soil texture - see note immediately above) to avoid seed sinking too deep - deep seed will have problems emerging if covered by mud and water.
- Broadcast
    - Seed rate - 80 to >120 kg seed/ha
- Anaerobically sow in rows
    - Seed rate - 60-80 kg/ha
    - Seed should not be planted deeper than 1 cm deep

Replanting bare patches

- One day after planting soak and incubate additional seed (e.g., 1 kg).
- Around three days after planting, broadcast additional seed in problem areas.
- 15 to 20 days after planting, transplant seedlings to bare patches, if required.

Photos

Wet direct seeded (WDS) field: Seed is planted into field prepared while saturated.

WDS requires good leveling and weed control. WDS fields can have problems of seed loss (rats and birds), snails, emergence, lodging, and weeds. Fields can be broadcast or sown in rows. Typically, 1-4 ha can be planted per day.

Dry Direct Seeded

Use **CLEAN SEED** - and increase yields by 5-20%!

- Weed pressure tends to be greater in dry direct seeded systems.
- Dry direct seeding can use more water and fertilizer if there is no natural hardpan to limit infiltration and percolation.
- **Wet/Dry seeding comparison**

Seeding depth

- Target planting depth - <1cm If drilled - 0.5 cm (maximum 1 cm - Variety dependent).
- Surface seeding can have problems of birds and rats - Broadcast and harrow if possible.
- Seed rate - 80 to >120 kg seed/ha.

Options

Broadcast

- Seed rate - 80to >120 kg/ha

Broadcast in furrows - modified California system

- Seed rate - 80 to >120 kg/ha.

- Prepare land with furrows 15 cm apart and 5-10 cm deep - broadcast and harrow lightly - seeds will emerge fairly strongly in rows.

Drill seed in rows

- Seed rate - 60-80 kg/ha.
- Seed should not be planted deeper than 1 cm deep.

Replanting bare patches

- Seeding bare patches - depends on soil moisture.

  One day after the field has sufficient moisture for germination, soak and incubate additional seed (e.g., 1 kg/ha).

  Three days after planting, broadcast additional seed in problem areas.

- 15 to 20 days after planting, transplant seedlings to bare patches.

Photos:
Dry direct seeded (DDS) field: Seed is usually planted into a field prepared while dry or moist. DDS requires good leveling and weed control.

Transplanted

Use **CLEAN SEED** - and increase yields by 5-20%!

Manually plant
Plant in rows - generally with a spacing of the order of 20 cm x 20 cm

Mechanically plant
Wait 1-2 days after land preparation to avoid plants sinking too deep - deep plants will have problems growing if covered by mud and water.

Replanting bare patches
15 to 20 days after planting, transplant seedlings to bare patches

- **Wet/Dry seeding comparison**

Photos:
Transplanted (TP) field: Your seedlings are planted into a field prepared while saturated. TP fields can have problems of snails. Hand TP requires 15-20 person days per ha. Mechanical TP can plant 1-2 ha per day. Hand transplanting.

Factors affecting crop uniformity

For maximum yields, plant stand must be uniform across the field. The critical factors are:

- Uniform seed and/or seedling distribution
- Good soil and water management - seeds will sink in soft soil and not emerge - or emerge unevenly
- Good **land leveling**
- Good water management, and
- Good control of **pests during crop establishment**

- With clay soils (like those at IRRI), wet direct seeding can have problems of emergence especially during the rainy season (rain seems to cause the seed to be buried deeper by the mud)
- See **Principles of crop establishment** for more information

Replanting (Filling gaps)

Transplanting
If TP, replant as soon as damage noted within 1 week of transplanting

Direct seeding
If DS, resow immediately that problem spots are noted, or transplant when seedlings around 5 cm (up to 2 weeks after planting).
If DS, pre-germinate additional seed 1-3 days after sowing field. Use this seed to fill in any gaps. Need some caution as herbicide applied may affect replanted spots.

Wet/Dry Direct Seeding Comparison

Wet direct seeded	Dry direct seeded
No nursery required	No nursery required
No seedling pulling	No seedling pulling
Need to pre-germinate & incubate seed	
Need improved water management	
Need improved leveling	
Surface seed can be attacked by birds and rats	Surface seed can be attacked by birds and rats
Weed more problematic	Weed much more problematic
Seed planted too deep (>1cm) will have problems emerging	

Comparison of factors associated with different crop establishment methods

Table key: TP = Transplanted; MTP = Mechanically transplanted; DDS = Dry direct seeded; WDS = wet direct seeded (puddled soil); L= low, H = high; + = little problem; ++++ = major limitation

	TP	MTP	DDS	WDS	Comments
Cost	L to H	H	L to H	L to H	Depends on labor markets
Land management					
Tillage			++		Affects soil-seed contact
Land leveling	+	++++	+++	++++	Low spots have problems of snails and of emergence in direct seeding

Water management	+	+++	++	+++	Drainage is critical in direct seeding. Use small canals around or through the field
Leaching			++		Greater problem if no puddling or subsoil compaction. Worse in dry direct seeded rice.
Pests					
Weed control	+	+	+++	++	Early seedling vigor and variety may decrease weeds through shading.
Red/weedy rice			+++	++	Can be reduced by water seeding (e.g., California) and use of good seed
Snails	++	++		+++	
Rats & birds			++	++	
Variety					
Lodging	++	++	+++	+++	Especially as N rates are increased
Early vigor			++	++	Especially for weed suppression
Seedling requirements		++			
Pre-planting seed preparation				++	Pre-germination is required and this can be a problem if seeding is delayed
Soil factors					
Soil texture	+	++	++	+++	Affects emergence and development of

					anaerobic conditions
Soil-seed contact			+++	+	
Depth to compaction layer		+++		++	Affects machine mobility - e.g., transplanter or seeder
Depth of planting			++	+++	Problem of anaerobic emergence
Rainfall during establishment			+	+++	Worse on wet direct seeded and in heavier soils

Target Plant Stands

Target plant stands are related to the target panicle counts. Target panicle counts are those that will give optimum yields. For example, panicles/m2 for maximum yield at IRRI (S Peng, pers. Comm.)

- Dry season Wet season
- 500-600 350-400

Tiller number is primarily driven by variety, N management, and plant stand established.

Example
For a transplanted crop 2 plants/hill @ 20 cm spacing, there are (5 x 5 x 2) = 50 plants/m2. Thus, in the dry season each plant will need to produce 500/50=10 panicles/plant.

The following table shows the tillering required to attain target panicle counts from different initial crop stands.

	Actual Plant Stand (/m2)	**Plants/** 10 x 10cm2	**Needed tillers/plant**	
			Dry season	**Wet season**
Broadcast	50	0.5	10-12	7-8
	100	1	5-6	3.5-4
	150	1.5	3.3-4	2.3-2.7
	200	2	2.5-3	1.75-2
		Plants/m row	Needed tillers/plant	
	Actual	**Row spacing (cm)**	**Dry**	**Wet**

	Plant Stand (/m2)				season	season
		15	20	25		
Direct Seeded	50	7.5	10	12.5	10-12	7-8
	100	15	20	25	5-6	3.5-4
	150	22.5	30	37.5	3.3-4	2.3-2.7
	200	30	40	50	2.5-3	1.75-2
			Plants/50cm row		Needed tillers/plant	

	Actual Plant Stand (/m2)		Row spacing (cm)		Dry season	Wet season
		15	20	25		
Direct Seeded	50	3.75	5	6.25	10-12	7-8
	100	7.5	10	12.5	5-6	3.5-4
	150	11.25	15	18.75	3.3-4	2.3-2.7
	200	15	20	25	2.5-3	1.75-2

Seed Rate

Why is seed rate important?

See the section on **target plant stands** for more background on why crop stand is important.

An obvious way to manipulate crop stand is through seed rate. For example:

10 kg seed/ha = 400,000 seeds/ha = 40 seeds/m2 (@ a thousand grain weight of 25 g)

Often less than 50% of seeds emerge, therefore, in the above example, 10 kg of seed would lead to < 20 plants/m2.

In direct seeded fields, farmers sow anywhere between 65 to >200 kg seed/ha. Therefore if the target number of panicles/m2 are: 500-600 for the Dry season, and 350-400 for the Wet season:

Seed rate kg/ha	Seeds/m2	Probable Emergence	Tillers	
			Dry Season	Wet Season
60	240	<120	>4	>3
100	400	<200	>2.5	>1.8
140	640	<320	>1.6	>1.1
180	720	<360	>1.4	>1
220	880	<440	>1.1	<1

Depending on the quality of the seed and crop management <10 to 70% of seed may establish:

Water Management

Principles of Water Management

Water is becoming increasingly scarce and expensive and it is important to find methods to reduce water consumption.

An even layer of water is important for:

- providing nitrogen from free living bacteria
- controlling weeds

Once a soil drops below FC saturation:

- Yield potential is lost (if around PI or later) and the maturity is likely to be delayed.
- Weeds can compete more freely.
- Dry tillage on cracking soils can reduce the amount of water lost to percolation by filling cracks and reducing crack development.
- Improved land leveling improves water management.
- Nutrient content in the water should be checked for possible inputs and/or toxicities.

Water Requirements

Target water depth for different growth stages of the rice crop.

Vegetative: Water level (cm)

- Germination Moist
- Seedling 0 (10-12 DAT, or 0-21 DAS for snail control)
- Tillering 2-5cm
- Stem elongation 5cm

Reproductive (35 days)

- Panicle initiation to Boot 5cm
- Heading 5cm
- Flowering 5cm

Ripening (30 days)

- 7. Milk 2-3cm
- 8. Dough 1-2cm
- 9. Mature drain

DAS = Days after seeding, DAT = Days after transplanting, Fields are drained about 7-10 days before physiological maturity (i.e., when 90-95% of grains have lost their green colour). This will typically be about 20 days after flowering.

To reduce water requirements:

- Fields should NOT be FLOODED weeks in advance for straw decomposition
- Less water is required with improved leveling.
- Wherever possible fields should be dry tilled to reduce water bypass flow (T Tuong - pers comm.).
- Saturate fields rather than having free standing water (requires greater management care)

Approximate water needs for a rice crop (from T Tuong):

- 31% evapotranspiration (aprox 800-1000 mm)
- 38% land preparation (approx 250 mm)
- 31% percolation and seepage (approx 250-400mm)

Calculate water requirements based on

- Evapotranspiration rates
- Crop length
- Percolation rates

Example
Crop length = 108 days - cut water 7 days prior to maturity

Water required for 101 d or less

ET = 5 mm/d

Crop demand = 101 * 5 = 505 mm

Percolation rate = 2 mm/d

Percolation losses = 101 * 2 = 202 mm

Water required for tillage = Saturate soil to 20 cm (Approx 50% of soil is space) and free water to 5 cm

> = 10 cm + 5 cm = 150 mm + percolation losses
> Percolation losses = 20 d * 2 mm = 40 mm
> Total demand = 505 + 202 + 150 + 40 = 897 mm

Early Season Field Drainage

(from T Tuong)

- Drain the field after the canopy has covered the field surface (around mid tillering), otherwise weeds will become problematic.
- Do not dry the soil after PI (as this will readily reduce yields).
- Transplanted crops - There is a rather small window (about 10-15 days) for transplanted rice allowing 2 drainage cycles (5 days each, no longer for crack prevention). If the soil cracks too much, then water can be lost upon rewetting to the subsoil.
- Wet seeded rice - there is a longer window, since the canopy closes earlier. You also can drain wet seeded rice a longer period, as it cracks less. The wet seeded rice may therefore give you more chances of water savings.
- Such drainage is practiced and has been proposed in a number of countries. The benefits detailed below are more anecdotal than scientifically established.

Why drainage?
Yield: No yield gain was obtained in the tropics by mid-season drainage. Though there were reported gains in temperate zone (Claims not supported by scientific papers, but more by annecdotes. e.g. gain of 1.5 t/ha

Methane emssion: Draining would reduce methane emmissions. Experiments at IRRI reduced methane emissions but are generally accompanied by an increase of N20 upon re-flooding of soil.

Water saving: Water is saved if drying is done properly (i.e., not too long, since over drying the soil leads to large cracks and more water losses. A recent study showed that the development of harmful cracks could be avoided by drying for about 5 days in transplanted rice and about 10 days in direct wet seeded rice (which has less cracks). The soil should be drained after the canopy has covered the field surface, otherwise weeds will become problematic. Drying the soil after PI is not recommended as this will easily affect yield.

Thus there is a rather small window (about 10-15 days) for transplanted rice allowing 2 drainage cycles (5 days each, no longer for crack prevention). For wet seeded rice, there is a longer window, since the canopy closes earlier. You also can drain wet seeded rice a longer period, as it cracks less. The wet seeded rice may therefore give you more chances of water savings.

Reduced lodging in wet seeded rice: This has not been proved, but the hypothesis is that lodging often occur in wet seeded rice because most of the roots are superficial (i.e. on the surface of the soil), the puddled soil does not have any soil strength to "hold the roots". Draining the soil may encourage roots to go deeper and more importantly increase surface soil compaction, thus increasing soil strength considerably.

Ineffective tillering: In China, field draining is used to reportedly keep the field with a "finite number of effective tillers"), allowing better ventilation and transmitting of sunlight into the space between rows of crops;

Better root system: Draining reportedly gives deeper and stronger roots ("white roots increase and black ones are reduced.

Improve soil aeration and oxygenation: Draining reportedly allows toxic substances to be eradicated and allows organic matter to decompose.

Increased N and P availability: Available N and P (mg/100 gm of soil) increased from before sun-drying (Wei and Song, 1989).

Other benefits: Extend the difference in ricefield temperature between day and night, and to reduce relative humidity in the field in order to reduce the possibility of diseases.

(References: Xu Zhifang, 1982. Irrigation of rice in China. Wuhan University of Hydraulic & Electric Engineering. Wuhan, Hubei Province, China.; Zhang Wei and Si-Tu Song. 1989. Influence of drainage practice on rice yield. pp 65-84 in Proc. of the 7th Afro-Asian Regional Conference, Vol. D.7, International Commission on Irrigation and Drainage, Tokyo.; T. Watanabe. 1992. Water budget in paddy field lots. P. 1-11 in Soil and Water Engineering for Paddy Field Management. Asian Institute of Technology, Bangkok.)

Water Quality - Critical Values

Water quality - major considerations

- Salinity
- Water infiltration rates
- Specific ion toxicity

Note: For each 1 ppm element in the water, the input in 1000mm is equivalent to 10 kg/ha.

Types of problems and critical values (See notes and key below):

Potential problem	Units	No problem	Slight to moderate problems	Severe problems
pH	no units	6.5-8.5	< 6.5; > 8.5	<6.5; >8.5
Salinity - ECw	dS/m = mmol/cm	<2.0	2.0-2.6	>2.6
Salinity - ECe	dS/m	<3.0	3.0-3.8	>3.8
TDS	mg/l	<450	450-2,000	>2,000
Infiltration	mm/day			
Specific ion toxicity				
Sodium - SAR	no units	<3	3-9	>9
Chloride	me/l	<4	4-10	>10
Boron	mg/l	<0.7	0.7-3.0	>3.0
Bicarbonate HCO_3^{2-}	me/l	<4	>4	>4

- Note: If pH is out of range (6.5-8.4) but with low salinity (e.g., < 0.2 dS/m) then there is likely no problem as the water has very low buffering. However, additional checks should be pursued for possible nutrient imbalance.
- The most likely problem with abnormal pH's is equipment damage as the water can be corrosive.
- ECw = irrigation water salinity
- ECe = Soil salinity as measured on a saturation extract
- SAR = Na/(square root(Ca+Mg/2)); Na, Ca and Mg in me/l

Reference: University of California. 1993. Integerated Pest Management for Rice. Second Edition. Statewide Integrated Pest Management Project. Division of Agriculture and Natural resources Publication 3280.

Nutrient Management

Introduction to Nutrient Management

The nutrient management section gives fertilizer recommendations by season and variety. Detailed information for nitrogen, phosphorus, potassium, zinc and sulphur is described within this section. Calendar nitrogen management strategies are provided according to the maturity class of the rice variety being grown. Information on how to use a SPAD meter to determine the amount of nitrogen to apply is also provided. A working example on how to estimate fertilizer requirements for nutrient use efficiency is described. As well, detailed information on the symptoms of plant nutrient deficiencies is explained for the user so that he/she can identify his/her nutrient problem in the field. Finally, nutrient conversions, fertilizer sources and solution culture are also given.

Principles of Nutrient Management

Note: Much of the material presented here comes from Dobermann, A. and Fairhurst, T. 1999. Field handbook. Nutritional disorders and nutrient management in Rice. IRRI, PPI/PPIC.

The key principles of nutrition are to provide the nutrients to the plant in the amount and at the time required. Nutrients vary in their mobility in the soil which affects their availability to the plant and loss from the system. N is highly mobile, P is immobile and K is intermediate. N is generally the greatest limiting nutrient. K is predominantly in the straw, which means that straw management greatly affects the K balance. N is greatly affected by management being readily lost as a gas (volatilized) when nitrates are exposed to anaerobic (no oxygen) conditions as when flooded or lost by leaching (washing out the bottom of the soil).

The key principles of N management are, the plant needs:

- Sufficient N during establishment and tillering to ensure adequate tillers/unit area.
- Sufficient N just prior to and during panicle initiation to ensure adequate panicle size (sink).
- Most of the plants N should be applied prior to or around panicle initiation.
- Sufficient N during grain filling to ensure production of photosynthate to fill the grains (generally 70% of the plant's needs at this stage come from remobilization from within the plant).
- Hold water at 5 cm and raise drains when making mid-season applications to reduce losses due to run-off.

Rules of thumb

- Everyday the crop is yellow, yield is being lost.

Amount

The total crop nutrient uptake per t grain produced is approximately:

- N - 15-20 kg
- P - 2-3 kg
- K - 15-20 kg

- If all straw remains in the field, K requirements can be reduced to 3-5 kg/ha per ton of grain yield if the straw is evenly distributed in the field.
- To reduce the risk of lodging and pests, do not apply excessive amounts of N fertilizer between panicle initiation and flowering stage, particularly in the wet season.

Season effects
N fertilizer requirement is smaller in rainy season crops (less sunshine, smaller potential yield) and larger in dry season crops (more sunshine, greater potential yield) where larger N application rates result in more tillers, higher leaf area and ultimately a larger grain yield.

Timing

- Most N should be applied prior to panicle initiation.
- Divide recommended N fertilizer rates of more than 60 kg N ha-1 per crop into 2-3 (wet season crop) or 3-5 (dry season crop) split applications. Use more splits especially with long duration varieties and in the dry season when crop yield potential is greater. N management is a balance of developing sink and source (plant size, leaf area).
- Avoid large basal N fertilizer applications (i.e. >50 kg N ha-1) in transplanted rice where growth is slow during the first 3 weeks after transplanting. Incorporate basal N into the soil before planting or sowing.
- A late N dose (at flowering) to delay leaf senescence and enhance grain filling, but only to healthy dry season crops with good yield potential.
- Apply N early to stimulate tillering to have sufficient source (leaves) and adequate productive tillers to produce panicles as sink, and
- Apply at panicle initiation to establish enough grain sites for filling during maturity
- K can be split with half applied as basal and half at mid tillering. Run-off must be avoided to ensure fertilizer is not lost. During on-farm trials of IRRI's mega project, K was split 50% basal and 50% at PI, but mainly to improve pest resistance. It may have some effect on lodging too, but the latter is mainly a nitrogen issue.

Water management

- In planted fields, lower or remove the floodwater before applying top-dressed N and then re-irrigate to enhance movement of N into the soil.
- To reduce volatilization, do not apply urea onto standing water under windy conditions before canopy closure, and at midday when the water temperature is highest.

Form

- Ammonium sources of N are better than other sources (e.g., nitrate).

Improving N fertilizer recovery

- Incorporate and keep soil continually saturated
- If soil alternates between aerobic and anaerobic fertilizer recovery is of the order of 30-40% or less for basal applications,
- With permanent flooding fertilizer recovery of split applications is of the order of 40-50% at mid-tillering and 60-70% at panicle initiation

Nutrient Management Strategies

Estimating Nutrient Requirements

Nutrient requirements depend upon:

- Target yield and soil nutrient supply.

To estimate fertilizer requirements you need to know

- Target yield.
- Crop yield with no fertilizer, and
- Fertilizer recovery.
  Type of fertilizer and recovery.
- Timing (which is dependent upon the maturity of the variety).

Work through the following two examples or link to the **Nutrient calculator**.

Example 1:
Target yield 5 t/ha
Yield without fertilizer 2.5 t/ha (mayuse yield estimate of farmers with low yields)
Yield to come from fertilizer = (5-2.5) t/ha = 2.5 t/ha
Approximate extra nutrients needed/t crop (from fertilizer or other sources):

- N = 15 to 20 kg N/ha, P = 2.5 to 3 kg P/ha, K = 15 to 20 kg K/ha
  Thus, to supply the additional 2.5 t grain/ha the crop will require an additional
- 2.5*15 to 20 = 37.5 to 50 kg N/ha
- 2.5*2.5 to 3 = 6.25 to 7.5 kg P/ha
- 2.5*15 to 20 = 37.5 to 50 kg K/ha
  - Typically N is the primary limitation and the other nutrients may or may not be needed depending on soil nutrient supply.
  - N recovery is typically of the order of 50%, thus to supply 37.5 to 50 kg N/ha to the crop, it will be necessary to apply between 75 and 100 kg N/ha. If slow release, deep placement, urea super granules or applications are made later, the fertilizer recovery can be increased and the rate required can be at the lower end.

If 1/3 is applied each at basal, mid tillering and panicle initiation, then the recovery is of the order:
1/3*.35+1/3*.45+1/3*.65 = 0.48
If there is no basal, 1/3 delayed, 2/3 panicle initiation, then the recovery is of the order of:
1/3*0.4+2/3*0.6 = 0.53

Example 2:
Target yield 8 t/ha
Yield without fertilizer 3 t/ha
Yield to come from nutrients added = (8-3) t/ha = 5 t/ha
Approximate extra nutrients needed/t crop:
N = 15 to 20 kg N/ha, P = 2.5 to 3 kg P/ha, K = 15 to 20 kg K/ha

- Thus, to produce the additional 5 t grain/ha the crop will require an additional 5*15 to 20 = 75 to 100 kg K/ha.
  - Typically N is the primary limitation and the other nutrients may or may not be needed depending on soil nutrient supply.
  - N recovery is typically of the order of 50%, thus to supply 175 to 200 kg N/ha to the crop, it will be necessary to apply between 150 and 200 kg N/ha. If slow release, deep placement or applications are made

later, the fertilizer recovery can be increased and the rate required can be reduced.

Click here to try the **Nutrient Calculator** (a simple computer program) which will prompt you for your target yield, and yield without fertilizer and then calculate the additional fertilizer required to meet such an increase in yield.

Calculating a Nutrient Management Scheme

Calculating a Nutrient Management Scheme is a two step process:

Step 1. Estimate the required N, P and K to meet the yield target
- Use the **Nutrient calculator** to estimate plant nutrient requirements.
- Record your nutrient levels required.
- Now multiply the result by a factor of two to get a fertilizer N requirement (this multiplication factor is because the efficiency of N recovery by the crop is usually around 50%).

Step 2. Decide on the best timing to apply nutrients/fertilizer.
- N - N Split options depend on the season (yield potential) and the variety
- P - Apply as basal to transplanted or early (prior to tillering) for direct seeded
- K - K split options depend on the amount required.

Note: Nutrients can be applied as organic or inorganic forms.

Leaf and Color Chart (LCC)

Introduction: Leaf Color Chart (LCC): A simple tool to manage nitrogen fertilizer in tropical rice

Farmers generally use leaf color as a visual and subjective indicator of the rice crop's nitrogen status (N) and need for N fertilizer application. The leaf color chart (LCC) reinforces the farmer's knowledge and provides a simple, easy-to-use, and inexpensive tool for efficient N management in rice. The LCC contains six gradients of green color from yellowish green (No. 1) to dark green (No. 6) and can guide nitrogen top-dressing in rice crops.

The color chart is an ideal tool to optimize N use in rice cropping, irrespective of the source of nitrogen applied - inorganic, organic, and/or biofertilizers. The successful adaptation and use of the color chart will promote timely and efficient use of N fertilizer in rice and minimize the fertilizer-related pollution of surface and ground water. Moreover, with the need-based N fertilizer application, rice plants will remain healthy, thereby reducing the need for application of pesticides. It is thus an eco-friendly tool in the hands of small farmers.

Critical color grades or LCC values
In general critical values are of the order of:

Rice type	Direct Seeded	Transplanted
Aromatic	-	3
Semidwarf	3	3.5-4

Hybrid	4	4

The critical leaf color reading for N topdressing in transplanted rice (TPR) may range from 3 for varieties with light green foliage (e.g. scented or aromatic rice varieties) to 3.5 to 4 for semi-dwarf indica varieties and 5 for rice hybrids. Similarly, the critical LCC grade is 3 for semi-dwarf indica and 4 for hybrids in direct wet-seeded rice (WSR) as established under the Philippines conditions. Crops showing leaf color below the critical values suffer from N deficiency and require immediate N fertilizer application to prevent yield losses. The critical LCC values can be determined after 1-2 seasons of testing for locally important varieties and crop establishment methods.

Guidelines for using the leaf color chart

1. Take LCC readings once every 7 to 10 days, starting from 14 days after transplanting (DAT) for TPR or 21 days after seeding (DAS) for WSR. The last reading is taken when the crop just starts flowering (first flowering).
2. Choose the topmost fully expanded leaf (Y leaf) for leaf color measurement because it reflects the N status of rice plants. The color of a single leaf is measured by placing the middle part of the leaf in front of the chart and comparing the leaf's color with the standard color chart. If the color of a rice leaf is judged to fall between two color grades/shades, the mean of the two values is taken as the LCC reading. For example, if the leaf color lies between the chart values No. 3 and No. 4, it is noted as 3.5.
3. During measurement, always shade the leaf being measured with your body, because leaf color reading is affected by Sun's angle and sunlight intensity. If possible, the same person should take LCC readings at the same time of the day.
4. Take readings of ten leaves at randomly chosen hills in a field. If six or more leaves show color grades below the established critical values, apply N fertilizer without delay.
5. The amount of N to be applied at different growth stages for semi-dwarf indica varieties are as follows:

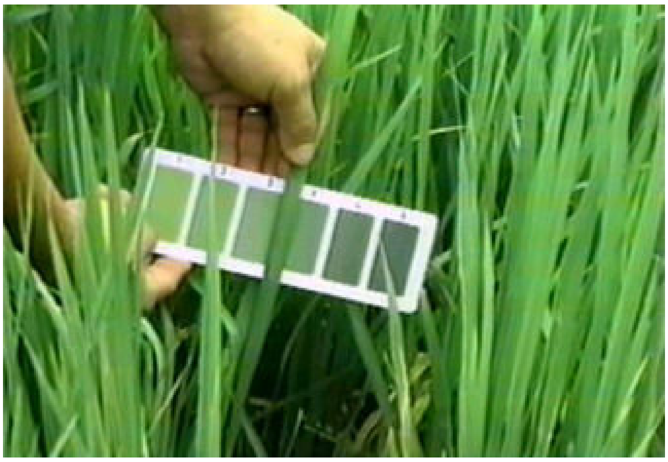
Transplanted rice	Dry season	Wet season (cloudy)
Early growth stage (14-28 DAT)	30 kg N/ha	20 kg N/ha
Rapid growth stage (29-48 DAT)	45 kg N/ha	30 kg N/ha
Late growth stage (49 DAT-flowering)	30 kg N/ha	20 kg N/ha

Direct Seeded rice	Dry season	Wet season (cloudy)
Early growth stage (21-34 DAT)	30 kg N/ha	20 kg N/ha
Rapid growth stage (35-55 DAT)	45 kg N/ha	30 kg N/ha
Late growth stage (56 DAT-flowering)	30 kg N/ha	20 kg N/ha

* apply the high N dose of 45 kg/ha in dry season and 30 kg/ha in wet season only once or twice during the rapid growth stage.

NB. To get optimum response to N fertilizer, other nutrients (P, K, S, Zn) must not be limiting. Therefore, adequate levels of other nutrients should be applied based on soil test or local recommendations.

Evaluating the LCC
Test fields can be divided into two equal parts: one for N fertilization with farmer's practice (FP) and the other for LCC-based N application (LCC). P, K, (S, Zn) are applied at locally recommended rates and time for both plots. Farmers can compare the total amount of N fertilizer used and grain yields obtained for the two methods to determine their relative efficiency and profitability. They an also evaluate the level of incidence of pests and diseases in both plots.


Leaf color chart being used in the field.

SPAD Meter

Critical SPAD values

Critical values	Direct seeded rice	Transplanted rice
Dry season	32	35
Wet season	32	32

Note: Use the above values for hybrids and varieties within plus/or minus 10 days of maturity of IR72

Dry season SPAD recommendations
Apply N at the rates indicated at the stages indicated, if the SPAD value is below the critical value

Dry Season: Semidwarf or hybrid
Transplanted or Direct seeded

	kg N/ha
First	30 Note: basal application can often be delayed to 10 DAT or 14 DAS
Second	40 (around Mid tillering)
Third	50-60 (around Panicle initiation)
Fourth	30 (around Flowering)

TOTAL	120-160

- Note: Flowering application
  - Seems more important in hybrids
  - Little risk of lodging, and will allow some varieties to express yield potential
  - Only apply if crop stand very good and free of diseases and pests

Wet season SPAD recommendations
Wet Season: Semidwarf or hybrid
Transplanted or Direct sown

Application	kg N/ha
Basal	20-30 Note: basal application can be delayed to 10 DAT or 14 DAS.
Second	30-50 (around Mid tillering to Panicle intiation - apply higher rates if close to PI).
Third	25 (an additional 25 can be applied if necessary).
TOTAL	75 -130

How to use the SPAD Meter
Explanation: The SPAD meter measures N (g)/leaf area (m2). Traditionally, N has been measured as N (g) /leaf weight (kg).

Calibration: There is a disk provided to check the accuracy of the meter, but there is also a calibration procedure.

Frequency of measurements
1. Start monitoring at 15-20 DAT, or DAS
2. Monitoring can be every 1-2 weeks. If near PI monitor weekly.
3. After a Nitrogen application, monitoring will generally not be required for at least 2 weeks.
4. Monitoring is not necessary after flowering.
5. In a replicated trial monitor 5 leaves/check plot (+ 30m^2) (if 4 replicates) (In production fields, 30 measurements are recommended.)

Taking measurements
1. Switch "ON"
2. Close for calibration until hear "BEEP".
3. Leaves should not have free water
4. You must shield the leaf from direct sunlight by having your back to the sun.
5. Leaves should be at the 1.5 "Y leaf" stage (1.4-1.6 adequate - count leaves from the top). First fully expanded leaf with the next emerging leaf approximately half way up its length.
6. Take readings between the leaf margin and the midrib (Avoid the midrib or only partially reading a leaf - i.e., edge - these give false readings).
7. Close until hear "BEEP".

8. To check a reading - take another reading on the same leaf - readings from the same leaf should be very similar.
9. Push "Average" to automatically calculate average for readings taken.
10. Clear data by pressing "ALL CLEAR DATA".

Note: You can remove leaves from the field for reading, but they need to be wrapped in a paper towel and put in an ice chest to avoid wilting.

N Split

N split options depend upon the yield target, **varietal** development, and the seeding method - choose the desired combination from the following Table.

	Method of Establishment	**Method of Establishment**
Season	*Transplanted*	*Direct-seeded*
High yield potential (7-8 t/ha or more)	click here	click here
Low yield potential (5-6 t/ha)	click here	click here

K Split

K rate (kg/ha)	**Recommended application practice**
<30	As basal or shortly after planting (10-15 days)
30-100	50% at basal or shortly after planting + 50% at panicle initiation
>100	50%at basal or shortly after planting + 30% at panicle initiation + 20% at flowering
Other	

- In direct seeded plots - apply first dose 10-15 days after planting
- Split K in at least two doses if soil is sandy with leaching
- K at flowering increases resistance to lodging and diseases in dense canopies if the yield target is high

Phosphorous and Potassium

P and K are typically applied as a basal application, although application at 10 DAS in direct sown crops may increase the efficiency of applied P recovery from 20 up to 35%. K can also be split - See K Split. In on-farm trials of the IRRI mega project, K is split 50% basal and 50% at PI, but mainly to improve pest resistance. It may have some effect on lodging too, but the latter is mainly a nitrogen issue.

Care is required to note whether P is calculated as P_2O_5 or K as K_2O. See **Nutrient conversions**.

IRRI (Philippines) conditions highlight application considerations.

For IRRI conditions: Basal P and K seem to be needed at high yield levels (>8t/ha) - therefore apply 30:30 (P:K) as basal. Given the high levels of K in the irrigation water at IRRI, a possible scheme is to apply N:P in the dry season (K being provided by the irrigation) and N:P:K in the wet season.

Requirements Based on Soil Test

P (kg/ha): Soil test reserves)	Wet Season	Dry Season
>10 ppm (Olsen)	10	20 (apply to maintain soil reserves)
<10 ppm (Olsen)	20	30

Or: If P < 10 ppm, apply around 3 kg P/ha/t yield. (Therefore will need 20-25 kg P uptake for 8 t/ha).

K apply 20-30 kg K/ha for both Wet Season & Dry Season as maintenance applications.

Check soil levels For example, station soil K levels at IRRI are high (>> 0.2 cmolc/kg - Test: NH4OAc - the generally accepted critical value). In addition, K in the irrigation water (15-20 ppm K) provides an annual input of 150-200 kg K/ha (assuming 1000 mm irrigation/season), although the same amount of K is lost through percolation. Response to fertilizer K on IRRI soil usually occurs at high yield levels (>8t/ha) so that K application in the DS should be standard.

Zinc and Sulphur

If Zn deficiency symptoms are

- mild - apply 5 kg Zn/ha (as $ZnSO_4$)
- severe - apply 20 kg Zn/ha (as $ZnSO_4$)

Rice plants can recover from Zn deficiency if the field is drained - a dry fallow increases the amount of available Zn.

Generally 1 ppm Zn is considered critical (Test: dilute HCl). At IRRI, if there is < 0.5 ppm, apply 5 kg $ZnSO_4$ as basal or dip roots in a 2-4% ZnO suspension. before planting (i.e., 20-40 g ZnO/l H2O). If fields ard not fallowed, then apply 10 kg Zn/ha every third year. Do root dipping in trials with high yield targets.

Sulfur (S) is not required if S > 9-10 ppm (Test: 0.5 M monocalcium phosphate).

The input of sulfur from the atmosphere is around 30-60 kg S/ha/year at Los Banos.

Examples of fertilizer management based on Variety maturity class

Choose one of **Variety** maturity class
Choose maturity class and variety desired based on yield potential, quality, and maturity class. Maturity class particularly affects nitrogen management.

	Days after seeding to:			Days after transplanting to:		
	Panicle Initiation	Flowering	Maturity	Panicle Initiation	Flowering	Maturity
Very early varieties						
IR36	50	73	103	35	60	90
Early Varieties						
IR72	55	78	108	40	65	95
Medium Varieties						
IR8	70	93	123	55	80	110

Nutrient Deficiencies

Major Plant Symptoms of Nutrient Deficiencies

- Root rotting - **Potassium** deficiency.
- Leaf characteristics:
    - Tip and edge burning - **Potassium** deficiency.
    - Chlorosis of young newly emerging leaves - **Iron** deficiency; **Nitrogen** deficiency.
    - General yellowing and dying of older leaves - **Nitrogen** deficiency.
    - Leaves yellow and dying after flooding - **Zinc** deficiency.

- Tillering - Reduced tillering - **Nitrogen** deficiency.
- Uneven flowering - **Phosphorus** deficiency.
- Late flowering - can be an indication of **Phosphorous** deficiency.

Nitrogen Deficiency

- Plants - stunted and yellow
- Leaves - general yellowing
    - In younger plants, the whole plant tends to be yellow.
    - In older plants, the deficiency is more pronounced in the older leaves.
- Tillering - severely reduced
- Flowering - may be delayed?.
- Grain formation - seeds/panicle is reduced.


Leaves are smaller in N-deficient plant.


Leaves are smaller in N-deficient plant.

Phosphorus Deficiency

NOTE: Phosphorus deficiency is difficult to detect unless severe.

- Roots - may be weakened
- Plants - stunted
- Leaves - dark green and erect. A purplish color may develop.
- Tillering - reduced
- Flowering may be delayed or uneven.
- Grain formation - reduced.

In general, both P and K have been identified in the past to be important for root health by preventing toxic Fe^{2+}. (There is still debate whether Fe-toxicity is caused due to direct toxic effects of Fe^{2+} or whether it is more the lack of K and/or P making the roots vulnerable. None-the-less, both P and K deficiency will lead to weakened root growth and it is usually seen in the form of many black (dead) roots compared to the healthy looking white or brown ones.

P-deficient plant is stunted, small and erect compared with the normal plant.

Tillering is reduced in P-deficient plot.

Potassium Deficiency

- Roots - may be rotten
- Plants - slightly stunted
- Leaves - appear droopy.
- Older leaves show leaf tip and leaf margin burning (yellowish/orange to brown discoloration starting at the tip and moving toward the base).
- Tillering - If severe, some reduction in tillering
- Flowering - unclear effect.
- Grain formation - Grain size and weight may be reduced.

In general, both P and K have been identified in the past to be important for root health by preventing toxic Fe^{2+}. (There is still debate whether Fe-toxicity is caused due to direct toxic effects of Fe^{2+} or whether it is more the lack of K and/or P making the roots vulnerable. None-the-less, both P and K deficiency will lead to weakened root growth and it is usually seen in the form of many black (dead) roots compared to the healthy looking white or brown ones.

Zinc Deficiency

- Plants can recover from symptoms soon after the field is drained
- Leaves
    - Lose their turgidity and tend to float on the water
    - Pale green color on the basal half of the leaf 2-4 days after flooding
    - Become chlorotic and start dying within 3-7 days after flooding
    - Chlorosis is generally most severe where the water is deepest
- Tillering
- Flowering
- Grain formation


Appearance of dusty brown spots on upper leaves of Zn-deficient plant.

Iron Deficiency

- Plants
- Leaves - Chlorosis of newly emerging leaves
- Tillering
- Flowering
- Grain formation

In general, both P and K have been identified in the past to be important for root health by preventing toxic Fe^{2+}. (There is still debate whether Fe-toxicity is caused due to direct toxic effects of Fe^{2+} or whether it is more the lack of K and/or P making the roots vulnerable. None-the-less, both P and K deficiency will lead to weakened root growth and it is usually seen in the form of many black (dead) roots compared to the healthy looking white or brown ones.

References (Nutrient Deficiencies)

Dobermann, A. and Fairhurst, T. 1999. *Field handbook. Nutritional disorders and nutrient management in Rice.* IRRI, PPI/PPIC.

Mueller, K.E. 1980. *Field problems of tropical rice.* IRRI.

Miley, W.N., Huey, B., Helms, R. *Growing rice on alkaline soils.* Cooperative extension service. Univ. of Arkansas, USDA, EL470.

Organic and Inorganic Fertilizer

Fertilizer Recovery (from S. Peng)

Recovery of top-dressed fertilizer varies throughout the life cycle (mainly as a function of root growth - i.e., root mat present to "intercept" N and water management).

In terms of N recovered from fertilizer N applied:

N application	Fertilizer recovery (%)
Basal	15-30

At midtillering	30-50
At panicle initiation	45-70
At flowering	35-60

Fertilizer Sources - What's Best?

Nitrogen (N)	Ammonium or ammonium-producing fertilizers are the best source of N. Super granules: It has been well established that about 20-25% of N fertilizer can be saved when urea briquettes (UB) or urea super granules (USG) are used for any targeted yield (6, 7, or 8 t/ha) of inbred varieties. In some cases, 10-15% higher grain yield are possible in addition to the saving of fertilizer. The rate of UB or USG can be 20-25% less than the recommended rates of prilled urea for any targeted yield if it is properly applied into anaerobic soil at about 5-10 cm depth.
Phosphorous (P)	Superphosphate (except in very acid soils) is usually the best P source.
Potassium (K)	KCl and K_2SO_4 are the most common K fertilizers used.

The major problem with UB and USG is that the application method is very labor intensive.

Fertilizer Content

	N	$P=P_2O_5$	$K=K_2O$	Ca	S
Anhydrous ammonia	82				
Urea	46				
Ammonium nitrate	34				
Ammonium sulfate	21				24
Complete (14:14:14)	14	6 = 14	12 = 14		11
Mono-ammonium phosphate (MAP)	12	22 = 50			1
Single superphosphate		9 = 21		19	11
Solophos 18%		8 = 18			
Solophos 34%		15 = 34			
Double/triple superphosphate		18 = 41			
Potassium chloride (muriate of potash)			49 = 59		
Zinc oxide (99.9%)					
Zinc sulfate					

Nutrient Conversions

- To convert elemental rate to fertilizer product rate:

- Product required (kg) = Elemental rate (kg/ha)* 100 * area (ha)/(Elemental content in fertilizer).
- (See link **fertilizer content**) nutrient content of typical fertilizers.
- Example: To apply Urea at a rate of 50 kg N/ha to 0.25 ha = 50 * 100 * 0.25/46 = 27.2 kg Urea.

• Converting between elemental and oxide forms - use the following table:
  - To convert Elemental to Oxide multiply by column (1).
  - To convert Oxide to Elemental multiply by column (2).

(1)	Elemental	Oxide	(2)
2.29	P	P_2O_5	0.437
1.20	K	K_2O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602

Organic Sources - Principles

(Note: For a more detailed discussion see Dobermann & Fairhurst, 2000)

All plants require a balanced supply of nutrients, water, oxygen, carbon dioxide and sunlight to grow well. Nutrients can come from either organic or inorganic sources including irrigation water, sediments, and from indigenous sources. Organic sources include biological N2 fixation sources (e.g., green manures and blue green algae), compost and animal manures. Each of these sources varies in their composition. For example, chicken manure has about twice the N content of cow manure – but this is still only about 1/20th the content of Urea by weight (Table 1). By contrast green manures such as Sesbania rostrata can accumulate 80–100 kg N ha-1 in 45–60 d of growth.

Table 1. Typical nutrient contents of organic materials (From Dobermann & Fairhurst, 2000).

Organic material	Water	C	N	P	K	Ca
	(% of fresh material)					
Fresh cattle manure	60	8-10	0.4-0.6	0.1-0.2	0.4-0.6	0.2–0.4
Composted cattle manure	35	30-35	1.5	1.2	2.1	2.0
Pig manure	80	5-10	0.7-1.0	0.2-0.3	0.5-0.7	1.2
Poultry manure	55	15	1.4-1.6	0.5-0.8	0.7-0.8	2.3
Sugarcane filter cake	75-80	8	0.3	0.2	0.1	0.5
Inorganic material						
Urea			46			
Ammonium sulphate			21			

kg nutrient t^{-1} fresh manure = % nutrient content × 10

Organic Sources - Advantages

One advantage of organic sources of nutrients is that they can provide a wide range of nutrients, whereas inorganic fertilizers typically only produce a single nutrient (e.g., urea – N) or a few (e.g., compound N,P,K). In addition, organic sources provide "bulk" matter that can be important in the sustenance of soil organic matter. The amount of organic matter required is simply a match between the indigenous soil supply (i.e., yield without fertilizer) and that required to attain the yield target. Deeper rooting green manures can draw nutrients from deeper in the soil profile – nutrients that would otherwise not be available to a relatively shallow rooting cereal. Green manures can also be useful in problem soils, especially in reclamation stages.

Organic Sources - Difficulties

While attractive ecologically, organic rice farming is only practiced in small areas due to the complexity of the system. Firstly, large amounts of organic material are often required, but not available. Secondly, labor requirements increase with the need to collect, cart and spread the material. Thirdly, yields are often lower. Thus, to be profitable, special organic rice markets are required. As a result while widely promoted due to the desired environmental and health benefits, practicalities often limit the adoption of manure application by farmers. Similarly, crop intensification, low seed availability and increasing labor costs often constrain the feasibility of green manure crops.

Organic Sources - Turnover

Organic matter turnover is higher in aerated systems (e.g., wheat-maize) relative to continuously flooded systems (rice-rice). Rice-wheat systems would be expected to be intermediate.

Straw management The fastest breakdown of straw is when the soil is moist (about 60% of water holding capacity), not wet (saturated) nor dry (Brandon et al., 1997). Thus, water can be saved by NOT saturating soil weeks in advance. At the same time, saturating fields for less time will improve mobility and field uniformity.

Recent data show that 50% decomposition of straw can occur in a normal fallow period of two months between two crops without any additional water. The only requirement is a shallow dry incorporation after harvest (A Dobermann, pers. Comm.).

Thus, when weather permits, shallow dry tillage is to be the standard practice. It will reduce water requirements and make the subsequent land management easier and better in terms of laser leveling.

Organic Sources - Niche

Dobermann and Fairhurst (2000) identify:

"the niche for prerice green manuring as the relatively short time span available for green manure growth when the soil moisture regime is unfavorable for cash cropping (e.g., flood-prone rainfed lowlands with coarse-textured soils). Ultimately, socioeconomic factors such as the cost of land, labor, and mineral N fertilizer determine the cost-effectiveness and adoption of prerice green manure technology by farmers. Given these constraints, green manure use is expected to decrease further in favorable rice-growing environments in the future."

Organic Sources - Straw Management

Early tillage and aerated decomposition of residue leads to improved nutrition of the subsequent rice crop due to enhanced N mineralization and P release.

The general nutrient requirements (kg) per ton of crop (grain and straw requirements) are:

	N	P	K	S	Ca	Mg
Grain (%)	1.05-1.4	0.15-0.25	0.25-0.33	0.06-0.15	0.05-0.09	0.02-0.013
Straw (%)	0.5-0.8	0.05-0.1	1.3-2.0	0.05-0.1	0.03-0.17	0.15-0.16
Crop uptake (kg)/t grain	15-22	2-4	15-25	0.15-0.25	-	-

The benefits of straw incorporation include:

1. Recycling of nutrients from straw without the trouble involved in common late incorporation and decomposition under anaerobic conditions.
2. Improved re-oxidation of the topsoil layer during the fallow period (important for long-term sustainability of soils).
3. Substantial water savings. Cracking is reduced and land soaking of the subsequent crop can be done much faster (not much bypass flow water losses). The soil will not get soaked too much and there will thus be better tractor mobility.
4. Volunteer control.

Reference: Brandon, D.M., Brouder, S., Chaney, D., Hill, J.E., Scardaci, S.C. and Williams, J.F. 1997. Rice straw incoproration. Agronomy fact sheet Series 1995-1. Dept. of Agronomy & Range Science. UC, Davis. (From UC Davis rice web site.)

The advantages of a plough fallow versus grass fallow are yet to be evaluated, but a shallow plough fallow seems to have advantages of improved residue decomposition and decreased water requirements when the field is wetted.

If weather permits, the field should be dry tilled within two weeks of harvest.

Solution Culture

The standard nutrient solution is from Yoshida et al (1976):

Macronutrient	ppm
N[1]	40
P	10
K	40
Ca	40

Mg	40
Mn	0.50
Mo	0.05
B	0.20
Cu	0.01
Zn	0.01
Fe	2.00

Recommended pH is 5.

Note:
N can be varied:
40 ppm until 3 weeks after transplanting
80 ppm at maximum tillering
40 ppm at 2 weeks after flowering
0 ppm at maturity

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Weed Management

Overview of Weed Management

This section on Weed management provides an overview of the cultural practices used and herbicides available to combat the growth of weeds. The user can choose to incorporate cultural practices or select the herbicide most appropriate for their crop establishment method. Information on herbicides is organized in a variety of ways: by manufacturer, establishment method, and alphabetically. More detailed information, such as chemical composition, is provided for each herbicide at the end of this section. This product list is composed of products typically available and used by farmers in Asia. It is not a complete list nor does it represent endorsement of use.

Principles of Weed Management

Weeds reduce yields by competing with the crop for light, nutrients and sometimes water. Timely control is required to avoid yield losses in the present season and avoid seeds produced for subsequent seasons. Weed management is becoming increasing important as farmers move to direct seeding and as water is becoming less available. Integrated weed management will rely on a range of practices to decrease weed pressures, including, good and timely land preparation, good land leveling, good water management, good crop establishment, healthy clean seeds, varieties with good early vigor and where necessary sound and appropriate use of agrochemicals.

- Some weeds are allelopathic - i.e., they excrete chemicals that are harmful to the crop.
- Control is critical during the first 15 to 20 days after seeding or transplanting, however other weeds may compete throughout the lifecycle.
- Later control may be needed to stop weeds from setting seeds, but yield will already have been affected by early competition.
- Good water management (including improved **Land leveling**) reduces weed burdens.
- Timely pre-planting tillage can reduce weed burdens e.g., till on moist soil and re-till after two weeks just prior to planting to kill germinating weeds.

Cultural Practices

- **Clean seed** - Only use good **clean seed** (free of weed seeds).
- **Level land** - Improved leveling improves water control and can significantly reduce weed pressure.
- **Tillage** - Tillage practices should be timed (e.g., 10-14 days between passes) such that weeds have time to germinate in between tillage operations and thus be killed by the succeeding operation. Timely tillage reduces weed pressure:

- **Crop rotation** - rotate crops and weed control practices to decrease weed build-up.

- **Variety selection** - Select varieties that are more competitive and that have faster earlier growth.
- **Method of planting**
    - Transplanting gives the plant a competitive advantage against weeds.
    - Direct seed in rows to faciliate hand or mechanical weeding.
- **Plant population and seed rate** - Higher populations of rice increase shading and reduce weed growth, but may increase crop lodging.
- **Manage water** - combined with good leveling, maintenance of a water layer in the paddy reduces the pressure of many weeds.

- **Control weeds in the crop**
  - Stop weeds from setting seed during the crop cycle (An old saying suggests that *1 year seeds = 7 year weeds*).
  - Make sure weeds do not set seed during or after harvest.
- **Clean irrigation systems** - prevent weeds from growing along bunds and irrigation canals - weed seed can pass along the irrigation system to your field.
- **Manage the fallow** - stop weeds from setting seed during fallow periods ("1 year seeds, 7 year weeds").

Herbicides

List of Herbicides and Manufacturers

2,4-D

Generic name:	2,4-D Amine
Other 2,4-D trade names:	Aqua Kleen, Demise, Esteron, Weed-B-Gone, Weedone, 2,4-D Amine, Shell 2,4-D Ester
Active chemical:	2,4-D (as an amine salt) 400 g/L
Produced by:	Agrochem
Used to control:	Annual sedges and broadleaves
Use in TPR or DS:	TPR or DS

Application information:

- **mode of action:** Selective, systemic, hormone-type herbicide. Salts are readily absorbed by the roots. Esters are readily absorbed by the foliage. Translocation occurs, with accumulation principally at the meristematic regions of shoots and roots. Esters tend to be more volatile than amine forms of 2,4-D.
- **action on weed: primarily post-emergence**
- **biochemistry:**Acts as a growth inhibitor.
- **recommended application rate (kg active ingredient/ha):**
  - Transplanted 0.5-0.8
  - Wet direct seeded 0.5-0.8
  - Dry direct seeded 0.5-0.8

  - Label 1) concentration: 3.5 to 6.5 TBSP / 16 L 2) spray volume: no information 3) spray rate: no information
- **recommended application time: Safe from fully tillered to pre-panicle initiation**
  - Transplanted 25 to 30 DAT
  - Wet direct seeded 21-28 Days after emergence (DAE)
  - Dry direct seeded 21 DAE
- **General instructions / field conditions:** weeds need to be above the water line. TPR : Drain field to expose weeds. Flood 2 to 3 days after application. DS : Lower water to expose weeds. Reflood within 2 to 3 days
- **use in herbicide mixtures:** no information

Advance (Butachlor + safener)

Generic name: Advance
Active chemical: Butachlor 350g/L Propanil 350g/L
Produced by: Monsanto
Used to control: Annual grasses, sedges and broadleaves
Use in TPR or DS: TPR and DS
Application information:

- **herbicide type:** selective, early post emergence, Propanil - contact
- **action on weed: pre-emergence to post (2 leaf stage)**
- **recommended application rate (kg active ingredient/ha):**
  - Transplanted 1.5-2 l product/ha
  - Wet direct seeded 1.5-2 l product/ha
  - Dry direct seeded 3-4 l product/ha
  - Label 1) concentration: 8 to 12 TBSP / 16L 2) spray volume :200L /ha 3) rate of spray: no information
- **recommended application time:**
  - Transplanted 6 to 10 DAT
  - Wet direct seeded 6 to 10 DAS
  - Dry direct seeded 7 to 10 DAS
- **water status on application:** DS : spray on saturated soil, flood field 1 to 3 days after application
- **use in herbicide mixtures:** no information

Agroxone (MCPA)

Generic name: Agroxone
Other trade names: Agroxone,Agritox, Hedonal, Zelan, Chiptox, Frasan, Vacate.
Active chemical: MCPA Potassium salt 400g/L
Produced by: ICI
Used to control: Wide range of weeds - Sedges and broadleaves.
Use in TPR or DS: TPR and DS
Application information:

- **mode of action:** Selective, systemic, hormone-type herbicide. Absorbed by the leaves and the roots. Translocation occurs, with accumulation pricipally at the meristematic regions of shoots and roots.

- **action on weed: post-emergence**
- **biochemistry:**Acts as a growth inhibitor.
- **recommended application rate (kg active ingredient/ha):**
    - Transplanted 0.8 (0.5-1.0)
    - Wet direct seeded 0.8 "
    - Dry direct seeded 0.8 "
    - Label 1) concentration: 1.5 to 2.5 L / ha 2) spray volume: no information 3) spray rate: no information
- **recommended application time: Safe from fully tillered to pre-panicle initiation**
    - Transplanted based on weed - 2 leaf to 28 DAE; 21 to 30 DAT
    - Wet direct seeded based on weed - 2 leaf to 28 DAE ; 25 to 30 DAS
    - Dry direct seeded based on weed - 2 leaf to 28 DAE ; 25 to 30 DAS
- **general instructions / field conditions:** weeds need to be above the water. TPR : Drain field to expose weeds. Flood 2 to 3 days after application. DS : Lower water to expose weeds. Reflood within 2 to 3 days.
- **use in herbicide mixtures:** no information

Basagran (Bentazon)

Generic name:	Basagran
Other trade names:	Galaxy, Storm, Benta
Active chemical:	Bentazon 480g/L
Produced by:	BASF
Used to control:	Perennial and annual sedges and broadleaves
Use in TPR or DS:	TPR or DS
Application information:	

- **mode of action:** Selective, contact herbicide, absorbed mainly by the foliage, with very little translocation. Also absorbed by the roots, with translocation acropetally in the xylem.
- **action on weed: post-emergence**
- **biochemistry: p**hotosynthetic electron transport inhibitor
- **recommended application rate (kg active ingredient/ha):**
    - Transplanted 0.75-2.0
    - Wet direct seeded 0.75-2.0
    - Dry direct seeded 0.75-2.0
    - Label 1) concentration: 2L / ha (6 to 13 TBSP / 16L) 2) spray volume: 500L / ha 3) spray rate: no information
- **recommended application time: weeds at 2-10 leaf stage**
    - Transplanted Depends on weed stage - but can be applied 15 to 30 DAT
    - Wet direct seeded Depends on weed stage
    - Dry direct seeded Depends on weed stage
- **water status on application:** weeds need to be above the water line, ensure weeds are wet
- **use in herbicide mixtures:** no information

Direk 800 (Butachlor + safener)

Generic name: Direk 800
Active chemical: Butachlor 800g/L + safener

Produced by: Monsanto
Used to control: Grasses, sedges and broadleaves
Use in TPR or DS: TPR or DS
Application information:

- **herbicide type:** selective
- **action on weed: pre-emergence**
- **recommended application rate (kg active ingredient/ha):**
    - Transplanted 0.75-1.0 (best to use Machete as safener not needed for TPR)
    - Wet direct seeded 0.75-1.0
    - Dry direct seeded 2.0-3.0
    - Label 1) concentration: 5 to 7.5 TBSP / 16L 2) spray volume: 200 to 300 L / ha 3) spray rate: no information
- **recommended application time:**
    - Transplanted 0-7 DAT
    - Wet direct seeded 2-5 DAS
    - Dry direct seeded 3-5 DBS-10-12 DAE
- **water status on application:** Apply to moist, puddled soil. Control water normally after applying, without submerging seedlings.
- **use in herbicide mixtures:** no information

Herbadox 330E (Pendimethalin)

Generic name: Herbadox 330E
Other trade names: Herbadox, Prowl, Stomp.
Active chemical: Pendimethalin 330g/L
Produced by: Cynamid
Used to control: *Echinochloa spp.*, some annual grasses, sedges and broadleaves
Use in TPR or DS: TPR and DS
Application information:

- **mode of action:** Selective herbicide, absorbed by the roots and the leaves. Affected plants die shortly after germination or following emergence from the soil.
- **action on weed: pre emergence or early post emergence**
- **biochemistry:** Inhibits cell division and cell elongation
- **recommended application rate (kg active ingredient/ha):**
    - Transplanted 0.75
    - Wet direct seeded 0.75
    - Dry direct seeded 0.75
    - Label 1) concentration: 1.0 to 1.5 kg ai / ha 2) spray volume: 260 to 400 L / ha depending on concentration per sprayload 3) spray rate: no information
- **recommended application time:** **Rice seed needs to have imbibed prior to application**
    - Transplanted 3 to 7 DAT
    - Wet direct seeded 2 DAS up to 6 DAS or before weeds obtain 2 leaf stage
    - Dry direct seeded 2 DAS up to 6 DAS or before weeds obtain 2 leaf stage
- **general instructions / field conditions:** There should be no flood water on the direct seeded fields at application. Residual moisture is needed for activation of the chemical, so irrigate within 7 days of application. TPR: maintain water depth at 3 to 5cm. Crop

injury / poor weed control may occur if applied to waterlogged soils, or if heavy rainfall occurs after application.

- **use in herbicide mixtures:** no information

Londax (Bensulfuron)

Generic name: Londax
Active chemical: Bensulfuron 100g/kg
Produced by: Du Pont
Used to control: Annual grasses, sedges and broadleaves
Use in TPR or DS: TPR and DS
Application information:

- **herbicide type:** selective
- **action on weed: pre to early post emergence**
- **recommended application rate (kg active ingredient/ha):**
    - Transplanted 0.5-0.7?
    - Wet direct seeded 0.5-0.7?
    - Dry direct seeded Not recommended?
    - Label 1) concentration: 500 to 700 g / ha 2) spray volume: 80 to 160 L / ha 3) spray rate: no information
- **recommended application time:**
    - Transplanted 4-10 DAT
    - Wet direct seeded 4-8 DAS
    - Dry direct seeded
- **water status on application:** Soil should be fully submerged when applying and water should be retained for at least 4 days.
- **use in herbicide mixtures:** compatible with commonly used herbicides

Machete (Butachlor)

Generic name: Machete
Other trade names: Machete, Butataf, Butanex, Farmachlor, Dhanuchlor, Rasayanchlor, Trapp, Direk.
Active chemical: Butachlor 600g/L
Produced by: Monsanto
Used to control: Grasses, some broadleaves and sedges
Use in TPR or DS: TPR and DS
Application information:

- **mode of action:** Selective, systemic herbicide, absorbed primarily through germinating shoots and secondarily by roots. Translocated throughout the plant, with higher concentration in the vegetative parts than the reproductive parts.
- **action on weed: pre emergence**
- **biochemistry:** Protein synthesis inhibitor.
- **recommended application rate (kg ai/ha):**
    - Transplanted 0.75-1.0

- Wet direct seeded 0.75-1.0 (Will cause phytotoxicity - best to use form with safener - Direk)
- Dry direct seeded 0.75-1.0 - Not recommended
- Label 1) concentration: 9 TBSP / 16L 2) spray volume: no information 3) spray rate: no information

- **recommended application time:**
  - Transplanted 0-4 DAT
  - Wet direct seeded 2-5 DBS
  - Dry direct seeded 2-5 DBS - Not recommended
- **General instructions / field conditions:** Needs a moist soil; DS : soil should be saturated on application and remain unflooded for 3 days. DS : apply to 3 to 5 cm of water, maintain water after application, but drain before seeding. TPR : apply on 3 to 5 cm water and retain water for 3 to 5 days after application.
- **use in herbicide mixtures:** can be tank mixed with 2,4-D to give pre emergence control of grasses, sedges and broadleaves.

Nominee 100 SC

Generic name: Nominee
Active chemical: Bispyribac-sodium (105.5 g/L Byspribac sodium)
Produced by: First produced by Kumiai (Japan), Nominee has been further developed by Bayer.
Used to control: Annual grasses, sedges and broadleaves
Use in TPR or DS: TPR or DS
Application information:

- herbicide type: selective
- action on weed: systemically-active post-emergence
- **recommended application rate (kg active ingredient/ha):**
  - Transplanted 250-300 mL product. Increase rate and spray volume when spraying later than 10 days after planting. Add non-ionic wetting agents.
  - Wet direct seeded 250-300 mL product. Increase rate and spray volume when spraying later than 10 days after planting. Add non-ionic wetting agents.
  - Dry direct seeded 250-300 mL product. Increase rate and spray volume when spraying later than 10 days after planting. Add non-ionic wetting agents.
  - Label 1) tablespoon (10 ml) per 16 liters of water.
  - spray rate (water volume): 160-320 l/ha.

- **recommended application time:**
  - Transplanted 2-4 leaf stage of weeds or 7-15 days after seedling or transplanting.
  - Wet direct seeded 2-4 leaf stage of weeds or 7-15 days after seedling or transplanting.
  - Dry direct seeded 2-4 leaf stage of weeds or 7-15 days after seedling or transplanting.

- water status on application: Drain excess water before spraying to expose target weeds, irrigate 1-3 days after application to obtain desired weed control.
- use in herbicide mixtures: Nominee 100 SC is compatible with commonly used insecticides and fungicides used in rice.

PRECAUTIONS: Do not smoke, eat or drink while handling the product. Wear protective clothing during mixing and application. Wash exposed skin thoroughly before eating and after work. Avoid contamination of any water supply with chemical or empty container. Remove contaminated clothing and wash thoroughly before reuse.

RE-ENTRY PERIOD: As soon as spray deposits have dried.

Rhonstar 25 (Oxadiazon)

Generic name: Rhonstar 25
Other trade names: Ronstar, Rhonstar.
Active chemical: Oxadiazon 250g/L
Produced by: Rhone-Poulenc
Used to control: Grasses, sedges and broadleaves
Use in TPR or DS: TPR and DS
Application information:

- **mode of action:** Selective, contact herbicide.
- **action on weed:** pre emergence for grasses, some post emergence for broadleaf
- **biochemistry:** Protoporphyrinogen oxidase inhibitor.
- **recommended application rate (kg ai/ha):**
  - Transplanted 0.375-0.75
  - Wet direct seeded 0.75-1.0
  - Dry direct seeded 0.75-1.0?
  - Label 1) concentration: 1.5 to 2 L / ha 2) spray volume: 500 to 600 L / ha 3) spray rate: no information
- **recommended application time:**
  - Transplanted 2-8 DAT
  - Wet direct seeded 3-5 DAS
  - Dry direct seeded 3-5 DAS
- **general instructions / field conditions:** works best with standing water or at least moist soil. TPR : Water should be at least 3 to 5cm deep and be maintained at this level for 2 to 5 days after application. DS : Soil must remain moist after application to maintain activity.
- **use in herbicide mixtures:** compatible with commonly used herbicides

Rhonstar (Oxadiazon)

Generic name: Ronstar
Active chemical: Oxadiazon 120g/L
Produced by: Rhone-Poulenc
Used to control: Annual grasses, sedges and broadleaves
Use in TPR or DS: TPR or DS
Application information:

- **herbicide type:** selective
- **action on weed:** pre emergence for grasses, some post emergence for broadleaf
- **recommended application rate (kg ai/ha):**
  - Transplanted 0.5-0.75
  - Wet direct seeded 0.75-1.0
  - Dry direct seeded 0.75-1.0?

    - Label 1) concentration: 120g ai / L 2) comes in shaker bottle 500ml bottle covers 1350 metre squared of dapog seedlings and 1250 metre squared of wet bed seedlings.
- **recommended application time:**
    - Transplanted 2-8 DAT
    - Wet direct seeded 3-5 DAS
    - Dry direct seeded 3-5 DAS
- **water status on application:** works best with standing water or at least moist soil
- **use in herbicide mixtures:** cannot be mixed, because already formulated.

Round Up (Glyphosate)

Generic name: Round Up
Other trade names: Round Up, Rodeo, Shackle, Spason.
Active chemical: Glyphosate (as isopropylamine salt) 480kg/L
Produced by: Monsanto
Used to control: Deep rooted perennial weeds and annual grasses, sedges and broadleaves.
Use in TPR or DS: Non-selective
Application information:

- **mode of action:** Non selective, systemic herbicide. Absorbed by the foliage, with rapid translocation throughout the plant. Inactivated on contact with soil.
- **action on weed: post emergence**
- **biochemistry:** Inhibits 5-enolpyruvylshikimate-3-phospahate synthesis (EPSPS),an enzyme of the aromatic acid biosynthesis pathway. This prevents synthesis of essential aromatic amino acids needed for protein biosynthesis.
- **recommended application rate (kg ai/ha):**
    - Transplanted 0.5 to 4.0 kg ai / ha (most perennials need 1.5 to 2.5 kg ai / ha)
    - Wet direct seeded "
    - Dry direct seeded "
    - Label 1) concentration: 2 L / ha 2) spray volume: 200 to 400 L / ha 3) spray rate: no information
- **recommended application time:** **Non-selective - apply before planting or sowing**..
    - Transplanted
    - Wet direct seeded
    - Dry direct seeded
- **recommended application time:** when weeds are actively growing
- **General instructions / field conditions:** Should not be applied to growing rice.
- **use in herbicide mixtures:** no information

Saturn 60 (Thiobencarb)

Generic name: Saturn 60
Other trade names: Saturn, Tamariz, Bolero, Siacarb, Saturno, Bigturn.
Active chemical: Thiobencarb 600g/L
Produced by: Rhone-Poulenc
Used to control: Annual grasses and sedges.
Use in TPR or DS: TPR and DS
Application information:

- **mode of action:** Selective herbicide, absorbed by coleoptile, mesocotyl, roots and leaves. Inhibits shoot growth of emerging seedlings.

- **action on weed: pre emergence and early post emergence**
- **biochemistry:** Protein synthesis inhibitor.
- **recommended application rate (kg ai/ha):**
    - Transplanted 1.0-1.5
    - Wet direct seeded 1.5-2.0
    - Dry direct seeded 3.0
    - Label 1) concentration: 1.5 L /ha for pre emergence grass control, 1.25 L /ha for post emergence sedge and broadleaf control. 2) spray volume: no direct information but gives details on number of sprayloads per hecatare and the amount of square metres covered per sprayload in relation to number of TBSP per 16L. 3) spray rate: no information.
- **recommended application time:**
    - Transplanted 3 DBT-10 DAT (at the 1 to 2 leaf stage of the weeds). (See below)
    - Wet direct seeded Pre-15 DAS (at the 1 to 2 leaf stage of the weeds). (See below)
    - Dry direct seeded Pre
- **recommended application time and water status:** TPR : 4 to 6 DAT for pre emergence control, 30 DAT for post emergence control. DS : pre emergence control: 1) apply on flooded fields 6 to 8 DAS. 2) apply on puddled soil, before flooding and seeding, then flood for 2 days and retain water for at least 2 days. Seed 3 to 5 days after flooding, drain before seeding. 3) apply on flooded field 5 to 7 DBS and retain water for at least 3 days. Drain before seeding. Post emergence control apply 30 DAS.
- **general instructions / field conditions:** TPR : Water should not be drained, or allowed to overflow, for 3 to 5 days after application. DS : Keep water low enough to avoid submerging the rice plants.
- **use in herbicide mixtures:** compatible with commonly used herbicides

Shell 2,4-D Ester (2,4-D)

Generic name: Shell 2,4-D Ester
Other 2,4-D trade names: Aqua Kleen, Demise, Esteron, Weed-B-Gone, Weedone, 2,4-D Amine,
Active chemical: 2,4-D isobutyl ester 400g/L
Produced by: Cynamid
Used to control: Grasses, sedges and broadleaves
Use in TPR or DS: TPR or DS
Application information:

- **mode of action:** Selective, systemic, hormone-type herbicide. Salts are readily absorbed by the roots. Esters are readily absorbed by the foliage. Translocation occurs, with accumulation principally at the meristematic regions of shoots and roots. Esters tend to be more volatile than other 2,4-D forms.
- **action on weed: primarily post-emergence**
- **biochemistry:**Acts as a growth inhibitor.
- **recommended application rate:**
    - Transplanted 0.5-0.8
    - Wet direct seeded 0.5-0.8
    - Dry direct seeded 0.5-0.8
    - Label 1) concentration: 5 to 6.5 TBSP / 16L 2) spray volume: high volume spray 3) spray rate: no information
- **recommended application time: Safe from fully tillered to pre-panicle initiation**
    - Transplanted 25 to 30 DAT

    - Wet direct seeded 21-28 Days after emergence (DAE)
    - Dry direct seeded 21 DAE
- **General instructions / field conditions:** weeds need to be above the water line. Apply when weeds are young, 2 to 6 leaf stage and clear of the water. TPR : Drain field to expose weeds. Flood 2 to 3 days after application. DS : Lower water to expose weeds. Reflood within 2 to 3 days
- **use in herbicide mixtures:** compatible with commonly used herbicides

Sofit 300 EC (Pretilachlor + safener)

Generic name: Sofit 300EC
Other pretilachlor trade names: Sofit, Rifit, **Solnet**, Gorbo, Sparkstar.
Active chemical: Pretilachlor 300g/L + safener
Produced by: Syngenta
Used to control: Grasses, sedges and broadleaves
Use in TPR or DS: TPR or DS
Application information:

- **mode of action:** Selective herbicide. It is taken up readily by the hypocotyls, mesocotyls and coleoptiles, and, to a lesser extent, by the roots of germinating weeds.
- **action on weed: pre emergence**
- **biochemistry:** Cell division inhibitor.
- **recommended application rate (kg ai/ha):**
    - Transplanted 0.3
    - Wet direct seeded 0.3
    - Dry direct seeded Not recommended
    - Label 1) concentration: 1 to 1.5 L / ha 2) spray volume: 160 to 224 L /ha 3) spray rate: no information
- **recommended application time:**
    - Transplanted pre TP and any time up to weed emergence - e.g., 1 DAT
    - Wet direct seeded 0-3 DAS
    - Dry direct seeded Not recommended
- **recommended application time:** 3 to 5 DAS, not more than 5 days after last soil disturbance
- **general instructions / field conditions:** best with moist flooded soil. DS : Apply on saturated soil, cannot be used in DS without an antidote (fenclorim). TPR : no information.
- **use in herbicide mixtures:** not recommended

Solnet (Pretilachlor)

Generic name: Solnet
Active chemical: Pretilachlor 500g/L
Produced by: Syngenta
Used to control: Grasses, sedges and broadleaves
Use in TPR or DS: TPR
Application information:

- **herbicide type:** selective
- **action on weed: pre emergence**
- **recommended application rate (kg ai/ha):**
    - Transplanted 0.3-0.5

  - Wet direct seeded Not recommended (use form of petilachlor with safener - **sofit**)
  - Dry direct seeded Not recommended
  - Label 1) concentration: 0.9 to 1.0 L / ha 2) spray volume: 160 to 240 L / ha 3) spray rate: no information
- **recommended application time: *****
  - Transplanted 2-4 DAT
  - Wet direct seeded Not recommended (use form of petilachlor with safener - sofit)
  - Dry direct seeded Not recommended (use form of pretilachlor with safener - sofit)
- **water status on application:** spray onto saturated soil, or 1cm standing water. Flood 1 day after application and retain water for 4 to 5 days at 2 to 3cm.
- **use in herbicide mixtures:** not recommended

Major Weeds and Reported Herbicide Effects

Herbicide Effect on Sedges

Herbicide	*Cyperus difformis*	*Cyperus iria*	*Cyperus rotundus*	*Fimbristylis milicea*
Bensulfuron Londax	S	S	R	S
Bentazon Basagran	S	S	MS	S
Butachlor Machete + safener Direk 800	S	S	R	S
Butachlor + Propanil Advance	S	S	R	S
2,4-D Amine Ester	S	S	R	S
MCPA Agroxone	S	MS	R	S
Oxadiazon Rhonstar 25 Ronstar	MS	S	R	
Pendimethalin Herbadox 330E	S	S	R	S
Pretilachlor Solnet + safener Sofit 300EC	S	S		S
Thiobencarb Saturn 60	S	S	R	S

KEY: **S** = Susceptible, **MS** = Moderately susceptible (Partial or inconsistent control), **R** = Resistant or no effect

Herbicide Effect on Grasses

Herbicide	***Digitaria ciliaris***	***Digitaria setigera***	***Echinochloa colona***	***Echinochloa crus-galli***	***Echinochloa glabrescens***	***Eleusine indica***	***Ischaemum rugosum***	***Leptochloa chinensis***	***Oryza sativa L. (red rice)***	***Paspalum distichum***
Bensulfuron Londax			S	S	S				R	R
Bentazon Basagran			R	R	R	R	R	R	R	R
Butachlor Machete + safener Direk 800			S	S	S	S	S	S	R	R
Butachlor + Propanil Advance			S	S	S	S	S	S	R	R
2,4-D Amine Ester			R	R	R	R	R	R	R	R
MCPA Agroxone			MS	R	R	R	R	R	R	R
Oxadiazon Rhonstar 25 Ronstar			S	S	S	S			R	R
Pendimethalin Herbadox 330E			S	S	S	S	S	S	R	R
Pretilachlor Solnet + safener Sofit 300EC			S	S	S			S	R	R
Thiobencarb Saturn 60			S	S	S	S	MS	S	R	R

KEY: **S** = Susceptible, **MS** = Moderately susceptible (Partial or inconsistent control), **R** = Resistant or no effect

Herbicide Effect on Broadleaf Weeds

Herbicide	*Ipomea aquatica*	*Monochoria vaginalis*	*Sphenoclea zeylanica*
Bensulfuron Londax		S	S
Bentazon Basagran		S	S
Butachlor Machete + safener Direk 800	R	S	S
Butachlor + Propanil Advance		S	S
2,4-D Amine Ester	S	S	S
MCPA Agroxone		S	S
Oxadiazon Rhonstar 25 Ronstar		S	S
Pendimethalin Herbadox 330E		S	S
Pretilachlor Solnet + safener Sofit 300EC		S	S
Thiobencarb Saturn 60		MS	

KEY: **S** = Susceptible, **MS** = Moderately susceptible (Partial or inconsistent control), **R** = Resistant or no effect

Some herbicides commonly used for weed control in transplanted (TPR) rice in Asia

Pre emergence (relative to weeds) herbicides for use in TPR:	
Herbicide	**Description**
Direk 800 (Butachlor + safener)	for a range of grasses, sedges and broadleaves
Herbadox 330E (Pendimethalin)	for *Echinochloa spp.*, some annual grasses, sedges and broadleaves
Londax (Bensulfuron)	for annual grasses, sedges and broadleaves. Some resistance reported
Machete (Butachlor)	for grasses, some broadleaves and sedges
Rhonstar 25 (Oxadiazon)	for grasses, sedges and broadleaves
Ronstar (Oxadiazon)	for grasses, sedges and broadleaves
Saturn 60 (Thiobencarb)	for annual grasses and sedges
Sofit 300EC (Pretilachlor + safener)	for grasses, sedges and broadleaves

Post emergence (relative to weeds) herbicides for use in TPR:	
Herbicide	**Description**
2,4-D Amine (2,4-D)	for annual sedges and broadleaves
2,4-D Ester (2,4-D)	for sedges, broadleaves and some grasses
Advance (Butachlor + Propanil)	for annual grasses, sedges and broadleaves
Agroxone (MCPA)	for a wide range of weeds - Sedges and broadleaves. Some resistance reported
Basagran (Bentazon)	for perennial and annual sedges and some broadleaves
Herbadox 330E (Pendimethalin)	for Echinochloa spp., some annual grasses, sedges and broadleaves
Londax (Bensulfuron)	for annual grasses, sedges and broadleaves. Some resistance reported
Nominee 100 SC	For annual grasses, sedges, and broadleaves.
Saturn 60 (Thiobencarb)	for annual grasses and sedges

See also, **Safety Consideration When Applying Agro-Chemicals**.

Some herbicides commonly used for weed control in direct seeded (DS) rice in Asia

Pre emergence (relative to weeds) herbicides for use in DS:	
Herbicide	**Description**
Direk 800 (Butachlor + safener)	for a range of grasses, sedges and broadleaves
Herbadox 330E (Pendimethalin)	for *Echinochloa spp*., some annual grasses, sedges and broadleaves
Londax (Bensulfuron)	for annual grasses, sedges and broadleaves. Some resistance reported
Machete(Butachlor)	for grasses, some broadleaves and sedges
Rhonstar 25 (Oxadiazon)	for grasses, sedges and broadleaves
Ronstar (Oxadiazon)	for grasses, sedges and broadleaves
Saturn 60 (Thiobencarb)	for annual grasses and sedges
Sofit 300EC (Pretilachlor + safener)	for grasses, sedges and broadleaves

Post emergence (relative to weeds) herbicides for use in TPR:	
Herbicide	**Description**
2,4-D Amine (2,4-D)	for annual sedges and broadleaves
2,4-D Ester (2,4-D)	for sedges, broadleaves and some grasses
Advance (Butachlor + Propanil)	for annual grasses, sedges and broadleaves

Agroxone (MCPA)	for a wide range of weeds - Sedges and broadleaves. Some resistance reported
Basagran (Bentazon)	for perennial and annual sedges and some broadleaves
Herbadox 330E (Pendimethalin)	for Echinochloa spp., some annual grasses, sedges and broadleaves
Londax (Bensulfuron)	for annual grasses, sedges and broadleaves. Some resistance reported
Nominee 100 SC	For annual grasses, sedges, and broadleaves.
Saturn 60 (Thiobencarb)	for annual grasses and sedges

See also, **Safety Consideration When Applying Agro-Chemicals**.

Conversions (active ingredient to product)

Click **here** to link to the product calculator for product conversion.

Examples to convert active ingredient to product (always check units):

METHOD 1:
Product required = [rate of active ingredient (a.i./ha)] / [(active ingredient in product) (a.i./l or a.i./kg)]

Example
- Apply Pretilachlor at 300 g a.i./ha
- Sofit = 300 g pretilachlor/l
- = 300 (g a.i./ha)/300 (g a.i./l) = 1 l Sofit

Alternate method

Product required = rate of active ingredient (a.i/ha) * 100/(percent active ingredient in product).

Example
- Apply Pretilachlor at 300 g a.i./ha
- Sofit = 300 g pretilachlor/l = 30% a.i.
- = 300 (g a.i./ha) * 100 /30 a.i. = 1000 g sofit/ha = 1 l Sofit (assume 1 g = 1 ml)

To estimate the product to add per tank and number of tank loads required:

Product/tank

= product (per ha) * tank capacity/Total liquid volume per ha to apply (water + agro-chemical).

Example
- Total volume of product/ha = 1 l
- Spray calibration (i.e., total application volume rate per ha) = 150 l/ha
- Sprayer capacity = 16 l
- Product/tank = 1 l/ha * 16 l / 150 l/ha = 0.107 l = 107 ml/tank

Number of tank loads required per field

= Total liquid volume to apply (water + agro-chemical) (l per ha) * Area (ha)/Tank capacity (l).

Example
- Calibration = (i.e., total application volume rate per ha) = 150 l/ha
- Tank capacity = 16 l
- Tanks/ha Area to apply = 0.6 ha
- Number of tanks loads = 150 (l/ha) * 0.6 ha/16 (l/tank) = 5.625 tank loads

Herbicides Reportedly Used on Rice Worldwide

Active Chemicals

- **Alphabetical listing or Recommended Chemicals for Weed and Brush control MP-44 Arkansas, 1996**
- **Bensulfuron**
- **Bensulfuron + Metsulfuron**
- **Bentazon**
- **Bentazon + MCPA**
- **Bifenox**
- **Bispyribac sodium**
- **Butachlor**
- **Butachlor + 2,4-D**
- **Butachlor G**
- **Butralin**
- **Clincher**
- **Cyhalofop butyl**
- **2,4-D**
- **Fenoxaprop**
- **Glyphosate**
- **MCPA**
- **Metsulfuron**
- **Molinate**
- **Oxadiazon**
- **Oxyfluorfen**
- **Pendimethalin**
- **Pendimethalin + Thiobencarb**
- **Thiobencarb**
- **Piperophos**
- **Pretilachlor**
- **Propanil**
- **Propanil + Molinate**
- **Pyrazosulfuron**
- **Quinclorac**
- **Quinclorac + Pendimethalin**
- **Quinclorac + Thiobencarb**
- **Thiobencarb**
- **Thiobencarb + 2,4-D**
- **Thiobencarb + Propanil**

Recommended Chemicals for Weed and Brush control MP-44 Arkansas, 1996

- **Pre-plant - vegetative knock-down**
  - **Glyphosate**
  - **2,4-D**
- **Pre-plant incorporated (water seeded only)**
  - **Molinate**
- **Pre-plant non-incorporated (water seeded only)**
  - **Thiobencarb**
- **Preemergence (dry seeded rice only)**
  - **Quinclorac**
- **Delayed preemergence (Dry seeded rice only)**
  - **Quinclorac**
  - **Quinclorac + Thiobencarb**
  - **Quinclorac + Pendimethalin**
  - **Thiobencarb**
  - **Pendimethalin**
- **Reduced rates, delayed preemergence (Dry seeded rice only)**
  - **Pendimethalin + Thiobencarb**
  - **Quinclorac + Thiobencarb**
  - **Quinclorac + Pendimethalin**
- **Early post-emergence (contact control)**
  - **Propanil**
- **Post-emergence (contact control)**
  - **Propanil + Molinate**
  - **Fenoxaprop**
  - **Propanil**
  - **Propanil + Molinate + Bensulfuron**
- **Post-emergence (contact and residual control)**
  - **Propanil**
  - **Propanil + Molinate + Thiobencarb**
  - **Propanil + Thiobencarb**
  - **Propanil + Pendimethalin**
  - **Quinclorac + Propanil**
  - **Propanil + Molinate**
- **Post-emergence (after flooding)**
  - **Molinate**
  - **Bensulfuron**
  - **Propanil**
  - **2,4-D**
  - **MCPA**

Bensulfuron (Sulfonylurea)
Application rate: 0.03 to 0.05 kg ai / ha
Application time: DS : 6 to 8 DAS TPR : 3 to 5 DAT
Use in TPR or DS: TPR and DS
General instructions / field conditions: Good crop safety on indica varieties, less safe on japonica types.
Weeds controlled: Sedges and broadleaves.
Biochemistry: Acts by inhibiting synthesis of the essential amino acids valine and isoleucine, hence stopping cell division and plant growth.
Mode of action: Selective, systemic herbicide, absorbed by foliage and roots, with rapid translocation to the meristematic tissues.
Trade names: Londax
Main index

Bentazon
Application rate: 1 to 2 kg ai / ha

Application time: TPR :15 to 17 DAT DS: no information
Use in TPR or DS: TPR and DS
General instructions / field conditions: Drain field to expose weed foliage. Ensure uniform wetting of the weeds.
Weeds controlled: Perennial and annual sedges, and broadleaves.
Biochemistry: Photosynthetic electron transport inhibitor
Mode of action: Selective, contact herbicide, absorbed mainly by the foliage, with very little translocation. Also absorbed by the roots, with translocation acropetally in the xylem.
Trade names: Basagran, Galaxy, Storm, Benta.
Main index

Bifenox (+ 2,4-D)(Diphenyl ether)
Application rate: 2.0 kg ai / ha (+ 0.5 kg ai / ha)
Application time: DS : 4 to 6 DAS (up to 2 leaf stage of rice) TPR : 4 DAT
Use in TPR or DS: TPR and DS
General instructions / field conditions: Highly toxic to direct seeded flooded rice.
Weeds controlled: Annual broadleaves and some grasses.
Biochemistry: Protoporphyrinogen oxidase inhibitor, acts by cellular membrane disruption and by inhibition of photosynthesis.
Mode of action: Selective herbicide, absorbed by the foliage, emerging shoots and roors. Limited translocation from roots and foliage to shoots.
Trade names: Modown, Tolkan Fox
Main index

Bispyribac sodium (Pyrimidinyloxybenzoic)
Application rate: 0.02 to 0.04 kg ai / ha
Application time: DS : 7 to 14 DAS
Use in TPR or DS: DS
General instructions / field conditions: Drain field to expose weeds. Ensure uniform wetting of the weeds.
Weeds controlled: Annual grasses (especially *Echinochloa spp.*), sedges and broadleaves.
Biochemistry: Acts by inhibition of acetolactate synthase, blocking branched chain amino acid biosynthesis.
Mode of action: Selective, systemic, post-emergence herbicide, absorbed by foliage and roots.
Trade names: Nominee
Main index

Butachlor (Chloroacetanilide)
Application rate: TPR 1 to 2 kg ai / ha DS 0.6 to 0.75 kg ai / ha
Application time: DS : 3 to 6 DAS TPR : 3 to 6 DAT
Use in TPR or DS: TPR and DS
General instructions / field conditions: DS : soil should be saturated on application and remain unflooded for 3 days. TPR : apply on 5 to 10 cm water and retain water for 3 to 5 days after application.
Weeds controlled: Annual grasses and some broadleaves.
Biochemistry: Protein synthesis inhibitor.
Mode of action: Selective, systemic herbicide, absorbed primarily through germinating shoots and secondarily by roots. Translocated throughout the plant, with higher concentration in the vegetative parts than the reproductive parts.
Trade names: Machete, Butataf, Butanex, Farmachlor, Dhanuchlor, Rasayanchlor, Trapp, **Direk**.
Main index

Butralin (Dinitroaniline)
Application rate: 2.0 kg ai / ha
Application time: DS : 2 to 3 DAS
Use in TPR or DS: DS
General instructions / field conditions: no information
Weeds controlled: Annual grasses.
Biochemistry: Cell division inhibitor.
Mode of action: Selective herbicide, absorbed by germinating seedlings, with slow translocation acropetally. Also acts as a growth regulator, supressing the growth of shoots, branches and suckers.
Trade names: Amexine, Tamex
Main index

Cyhalofop butyl (Polycyclic alkanoic acid)
Application time: DS : 7 to 14 DAS
Use in TPR or DS: DS
General instructions / field conditions: Drain field to expose weeds. Ensure uniform wetting of the weeds.
Weeds controlled: Annual grasses
Biochemistry: Inhibition of acetyl CoA carboxylase. Selectivity is due to the differential metabolism of the molecule by rice and target grass weeds.
Mode of action: Selective, post emergence herbicide.
Trade names: Clincher
Main index

2,4-D (Aryloxyalkanoic acid)
Application rate: 0.5 to 1.0 kg ai / ha
Application time: TPR : 21 to 28 DAT DS : 21 to 28 DAS
Use in TPR or DS: TPR and DS
General instructions / field conditions:TPR : Drain field to expose weeds. Flood 2 to 3 days after application. DS : Lower water to expose weeds. Reflood within 2 to 3 days.
Weeds controlled: Sedges and broadleaves.
Biochemistry: Acts as a growth inhibitor.
Mode of action: Selective, systemic, hormone-type herbicide. Salts are readily absorbed by the roots. Esters are readily absorbed by the foliage. Translocation occurs, with accumulation principally at the meristematic regions of shoots and roots.
Trade names: Aqua Kleen, Demise, Esteron, Weed-B-Gone, Weedone, **2,4-D Amine**, **Shell 2,4-D Ester**
Main index

Fenoxaprop (Polycyclic alkanoic acid)
Application rate: 0.04 to 0.18 kg ai / ha
Application time: Rice is tolerant of this herbicide from the 3 leaf stage till early tillering.
Use in TPR or DS: DS
General instructions / field conditions: This herbicide should not be applied with phenoxy compounds.
Weeds controlled: Annual and perennial grasses.
Biochemistry: Fatty acid synthesis inhibition in grasses.
Mode of action: Selective herbicide with contact and systemic action. It is absorbed principally by the leaves, with translocation acropetally and basipetally to the roots or rhizomes.
Trade names: Whip
Main index

Glyphosate (Organophosphorous)
Application rate: 0.5 to 4.0 kg ai / ha (most perennials need 1.5 to 2.5 kg ai / ha)
Application time: Before planting or sowing.
Use in TPR or DS: TPR and DS
General instructions / field conditions: Should not be applied to growing rice.
Weeds controlled: Deep rooted perennial weeds and annual grasses, sedges and broadleaves.
Biochemistry: Inhibits 5-enolpyruvylshikimate-3-phospahate synthesis (EPSPS),an enzyme of the aromatic acid biosynthesis pathway. This prevents synthesis of essential aromatic amino acids needed for protein biosynthesis.
Mode of action: Non selective, systemic herbicide. Absorbed by the foliage, with rapid translocation throughout the plant. Inactivated on contact with soil.
Trade names: Round Up, Rodeo, Shackle, Spason.
Main index

MCPA (Aryloxyalkanoic acid)
Application rate: 0.5 to 1.0 kg ai / ha
Application time: TPR : 21 to 28 DAT DS : 21 to 28 DAS
Use in TPR or DS: TPR and DS
General instructions / field conditions:TPR : Drain field to expose weeds. Flood 2 to 3 days after application. DS : Lower water to expose weeds. Reflood within 2 to 3 days.
Weeds controlled: Sedges and broadleaves.
Biochemistry: Acts as a growth inhibitor.

Mode of action: Selective, systemic, hormone-type herbicide. Absorbed by the leaves and the roots. Translocation occurs, with accumulation pricipally at the meristematic regions of shoots and roots.
Trade names: Agroxone, Agritox, Zelan, Chiptox, Frasan, Vacate.
Main index

Metsulfuron (Sulfonylurea)
Application rate: 0.004 to 0.006 kg ai / ha
Application time:12 DAS
Use in TPR or DS:DS
General instructions / field conditions: Drain field to expose weeds. Ensure uniform wetting of the weeds.
Weeds controlled: Sedges and broadleaves.
Biochemistry: Inhibits synthesis of branched chain amino acids. Inhibits synthesis of the essential amino acids valine and isoleucine, hence stopping cell division and plant growth.
Mode of action: Selective, systemic herbicide absorbed through the roots and foliage, with rapid translocation acropetally and basopetally. Susceptible plants cease growth almost immediately after post-emergence treatment and are killed in 7 to 21 days.
Trade names: Quit, Ally, Malban.
Main index

Molinate (Thiocarbamate)
Application rate:2.5 to 5.0 kg ai / ha
Application time: From pre-sowing to post-emergence.
Use in TPR or DS: TPR and DS
General instructions / field conditions: Water is needed to activate the chemical. Once applied continuous water cover must be maintained. If applied pre-flood then water is needed as soon as possible. If applied post-flood, then water needs to be raised to cover weed foliage for 4 to 6 days.
Weeds controlled: Grasses (particularly *Echinochloa spp.*) and broad leaves.
Biochemistry: Inhibits lipid metabolism.
Mode of action: Selective, systemic herbicide. Rapidly absorbed by roots, with translocation acropetally to the leaves. It inhibits germination.
Trade names: Ordram, Arrosolo, Sakkimol.
Main index

Oxadiazon
Application rate: 0.375 to 0.5 TPR 0.75 to 1.5 DS
Application time: TPR : 2 to 8 DAT DS : 4 to 6 DAS
Use in TPR or DS: TPR and DS
General instructions / field conditions: TPR : Water should be at least 3 to 5cm deep and be maintained at this level for 2 to 5 days after application. DS : Soil must remain moist after application to maintain activity.
Weeds controlled: Annual grasses and broadleaves.
Biochemistry: Protoporphyrinogen oxidase inhibitor.
Mode of action: Selective, contact herbicide.
Trade names: Ronstar, **Rhonstar**.
Main index

Oxyfluorfen (Diphenyl ether)
Application rate: 0.15 to 0.72 kg ai / ha
Application time: TPR : 4 DAT DS : 3 to 6 DAS
Use in TPR or DS: TPR and DS
General instructions / field conditions: Most active as a post-emergence treatment when weeds are small. Requires light for activity.
Weeds controlled: Grasses and broadleaves (more effective on broadleaves).
Biochemistry: Protoporphyrinogen oxidase inhibitor.
Mode of action: Selective, contact herbicide. Absorbed more readily by the foliage (and especially the shoots) than by roots, with very little translocation.
Trade names: Goal, Koltar, Galigan.
Main index

Pendimethalin (Dinitroaniline)
Application rate: 0.75 to 2.0 kg ai / ha
Application time: TPR : 4 DAT DS : up to 6 DAS

Use in TPR or DS: TPR and DS
General instructions / field conditions: There should be no flood water on the field at application. Residual moisture is needed for activation of the chemical, so irrigate within 7 days of application.
Weeds controlled: Annual grasses.
Biochemistry: Inhibits cell division and cell elongation
Mode of action: Selective herbicide, absorbed by the roots and the leaves. Affected plants die shortly after germination or following emergence from the soil.
Trade names: Herbadox, Prowl, Stomp.
Main index

Piperophos (Organophosphorous)
Application rate: 0.3 to 0.5 kg ai / ha
Application time: TPR : 2 to 8 DAS DS : 4 to 8 DAS (at 2 to 4 leaf stage of the weeds).
Use in TPR or DS: TPR and DS
General instructions / field conditions: Can be used in combination with with 2,4-D or cinosulfuron, in tropical areas, to widen the spectrum against broadleaves.
Weeds controlled: Annual grasses and sedges.
Biochemistry: no information.
Mode of action: Selective, systemic herbicide, absorbed by the roots, coleoptiles and leaves of young plants.
Trade names: Rilof.
Main index

Pretilachlor (Chloroacetanilide)
Application rate: 0.3 to 0.5 kg ai / ha
Application time: TPR : pre transplanting and any time up to weed emergence, DS : 0 to 3 DAS.
Use in TPR or DS: TPR and DS
General instructions / field conditions: DS : Apply on saturated soil, cannot be used in DS without an antidote (fenclorim). TPR : no information.
Weeds controlled: Annual grasses, sedges and broadleaves.
Biochemistry: Cell division inhibitor.
Mode of action: Selective herbicide. It is taken up readily by the hypocotyls, mesocotyls and coleoptiles, and, to a lesser extent, by the roots of germinating weeds.
Trade names: Sofit, Rifit, **Solnet**, Gorbo, Sparkstar.
Main index

Propanil (Anilide)
Application rate: 2 to 6 kg ai / ha
Application time: Should be applied when most weeds have emerged and are at the 2 to 3 leaf stage. DS : 7 to 12 DAS, TPR : any time up to panicle initiation.
Use in TPR or DS: TPR and DS
General instructions / field conditions: DS : Drain field to expose weeds. Ensure uniform wetting of the weeds. TPR : Lower water to expose the weeds, 24 hours before application. Raise water level 1 to 3 days after application, before any new weeds emerge. The herbicide should not be applied if rain is expected within 5 to 6 hours after application. The herbicide should not be applied at late tillering stages (60 DAT). There needs to be an interval of 14 days before and after spraying, before applications of carbamates and organophosphorous compounds can be made.
Weeds controlled: Grasses and broadleaves.
Biochemistry: Photosynthetic electron transport inhibitor.
Mode of action: Selective contact herbicide, with a short duration of activity.
Trade names: Stam, Surcopur, Stampede, Nox, Propasint, RiceNil, Riselect.
Main index

Pyrazosulfuron (Sulfonylurea)
Application rate: 0.012 to 0.03 kg ai / ha
Application time: Pre and early post emergence.
Use in TPR or DS: TPR and DS
General instructions / field conditions: no information.
Weeds controlled: Annual and perennial sedges and broadleaves.
Biochemistry: Inhibits synthesis of branched chain amino acids. Inhibits synthesis of the essential amino acids valine and isoleucine, hence stopping cell division and plant growth.

Mode of action: Systemic herbicide, absorbed by roots and / or leaves and translocated to the meristem.
Trade names: Sirius, Act, Agreen, Sparkstar, Billy.
Main index

Quinclorac (Quinolinecarboxylic acid)
Application rate: 0.25 to 0.375 kg ai /ha
Application time: TPR : 3 to 5 DAT DS : 6 to 12 DAS
Use in TPR or DS: TPR and DS
General instructions / field conditions: Drain field to expose weeds. Ensure uniform wetting of the weeds.
Weeds controlled: Annual grasses.
Biochemistry: Weak auxin activity.
Mode of action: Selective herbicide. Rapidly absorbed through the foliage. Plant response is similar to IAA or auxin-type herbicides, of the class benzoic acids and pyridine compounds.
Trade names: Facet, Queen.
Main index

Thiobencarb (Thiocarbamate)
Application rate: 1.5 to 4.0 kg ai / ha
Application time: TPR : 3 to 8 DAT DS : 6 DAS (at the 1 to 2 leaf stage of the weeds).
Use in TPR or DS: TPR and DS
General instructions / field conditions: TPR : Water should not be drained, or allowed to overflow, for 3 to 5 days after application. DS : Keep water low enough to avoid submerging the rice plants.
Weeds controlled: Annual grasses and sedges.
Biochemistry: Protein synthesis inhibitor.
Mode of action: Selective herbicide, absorbed by coleoptile, mesocotyl, roots and leaves. Inhibits shoot growth of emerging seedlings.
Trade names: Saturn, Tamariz, Bolero, Siacarb, Saturno, Bigturn

Major Weeds of Rice in the Tropics

Major Weeds of Rice in the Tropics

List of 4 sedges, 10 grasses and 3 broadleaves affecting rice in the Tropics

Weed name	Weed growth habit and weed nature	Typical weed height (cm)	Philippine common name (Tagalog)
SEDGES			
Cyperus difformis	Erect, smooth, densely tufted annual sedge; Life cycle - approx 30 d	20-70	ballayang
Cyperus iria	Smooth, tufted, annual sedge; Prolific seed production	20-60	paiung-paiung
Cyperus rotundus	Erect, tuber forming, perennial sedge; Persistent, produces many tubers	15-20	mutha
Fimbristylis miliacea	Erect, tufted, annual sedge; Produce many seeds and germinate throughout the season	20-70	ubod-ubod
GRASSES			
Digitaria ciliaris	Prostrate short lived perennial grass	20-60	
Digitaria setigera	Short lived perennial grass	>100	
Echinochloa colona	Smooth, tufted annual grass	70-75	pulang puit
Echinochloa crusgalli	Erect annual grass; Prolific seed producer. Tillers profusely, grows throughout the year and early on resembles rice	Up to 200	daua-daua
Echinochloa	Erect annual grass; Ecologically similar to rice	50-100	bayakibok, daua-daua

glabrescens			
Eleusine indica	Smooth or slightly hairy, prostrate to ascending annual grass; Prolific seed producer. Can complete several life cycles per year.	30-90	sabung-sabungan
Ischaemum rugosum	Aggressive, erect or straggling, tufted annual grass; Vigorous and aggressive. Resembles rice early on.	60-120	tinitrigo
Leptochloa chinesis	Stringly tufted annual or short lived perennial grass; Propogates from cuttings and therefore spread by tillage	30-100	palay-maya
***Oryza sativa* L. (red rice)**	Closely related to cultivated rice; Typically shatter before harvest		
Paspalum distichum	Prostrate, spreading, perennial grass; Spreads aggressively through stolons.	30-60	luya-luyang dagat, pagetpet
BROADLEAF WEEDS			
Ipomea aquatica	Smooth widely spreading perennial broadleaf vine; Fast growing, roots at nodes		kangkong
Monochoria vaginalis	Annual, semiaquatic broadleaf; Seeds germinate throughout the season - aggressive in high N soils	40-50	biga-bigaan
Sphenoclea zeylanica	Erect, smooth stemmed, annual broadleaf; Grows and flowers throughout the year	30-150	silisilihan

Sedges

*S*edge

Cyperus difformis

Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

*S*edge

Cyperus iria

Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

***S*edge**

Cyperus rotundus

Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Sedge

Fimbristylis miliacea

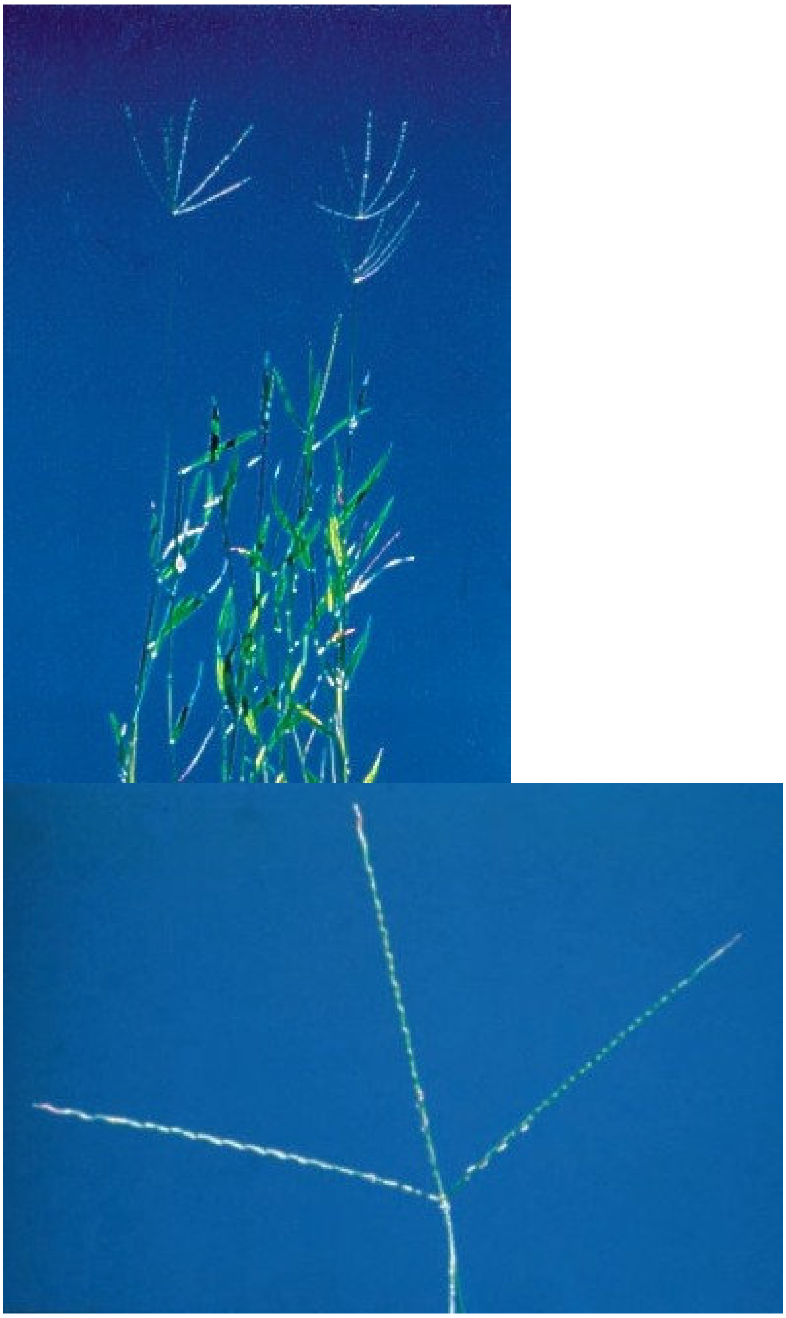
Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grasses

Grass

Digitaria ciliaris
Plant & inflorescence

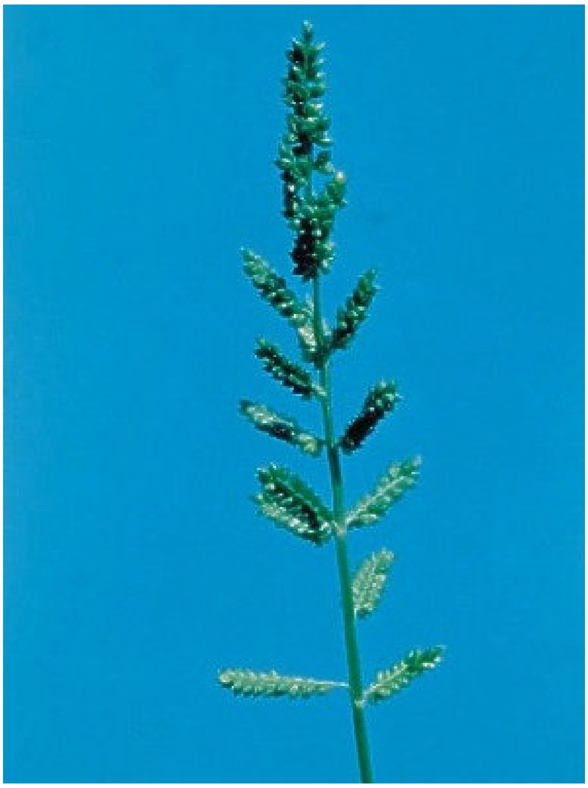


Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Echinochloa colona

Inflorescence



Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Echinochloa crusgalli

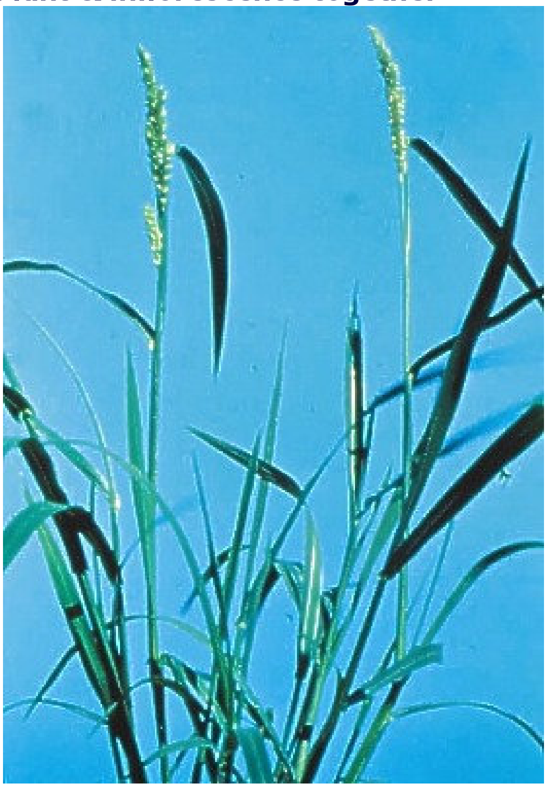
Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Echinochloa glabrescens

Plant & inflorescence together



Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Eleusine indica

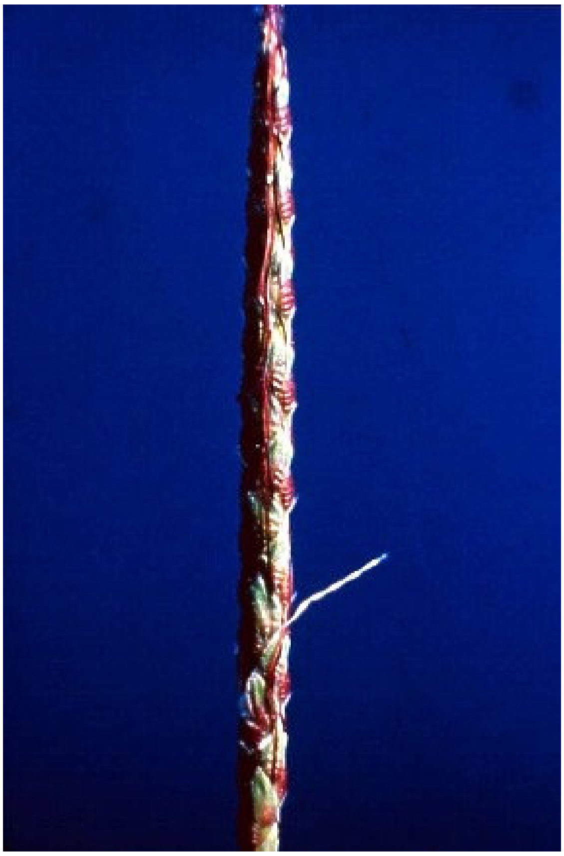
Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Ischaemum rugosum

Plant & inflorescence



Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Leptochloa chinensis

Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Grass

Red rice (Oryzae sativa)

Inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Broadleaf Weeds

Broadleaf

Ipomea aquatica

Plant & inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Broadleaf

Monochoria vaginalis

Plant

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

Boadleaf

Sphenoclea zeylanica

Plant & Inflorescence

Photos from: Mueller, K.E. 1983. *Field Problems of Tropical Rice. Revised. International Rice Research Institute*. Los Banos, Philippines. (Based on the original 1970 publication)

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2. Ampong-Nyarko, K. and De Datta, S.K. (1991). Weed Control In Rice. IRRI. Philippines.

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6. Thomson, W.T. Agricultural Chemicals. Book II Herbicides. Thomson Publications, Fresno, Ca., USA

Insect Management

Introduction to Insect Management

This section on insect management outlines information on common pests that might be encountered in rice fields. Information about these pests is laid out in a variety of ways to help the user identify the pest. The most common pests for each crop stage are identified. Identification is also achieved by identifying damage symptoms and field problems (such as leaf or grain damage). Control recommendations accompany the text. Integrated pest management (IPM) and field scouting procedures are included in some detail. Depending on the pest, some of the recommendations include cultural practices while for other insects, a possible agro-chemical may be suggested. Detailed information about each insecticide mentioned is provided at the end of this section.

Principles of Insect Management

- The type of damage has to be considered in terms of the plant stage and the plant's ability to compensate for any damage.
- Early foliar damage is rarely a problem. However, cutting leaves just before transplanting can reduce yields. Also, see Bunnarith et al. (2000) on cases of yield loss due to leaf cutting. The plant can compensate, although very heavy leaf loss (>50%) may delay development and maturity.
- Early tiller loss up to and just after PI may not be problematic, if other tillers can compensate.
- Late panicle and grain loss will likely reduce yield, as rice has little flexibility in terms of kernel weight. None-the-less studies on whiteheads caused by stem borer have indicated up to 1 whitehead/hill in hills producing 20 or more productive tillers do not generally affect yield.
- Pests typically are more mobile and multiply more quickly than beneficial insects. Therefore, early pesticide applications will generally ultimately benefit pests. Effects depend on life cycles and ability to reproduce.
- All losses and actions must be balanced against the cost. Calculate the amount of grain required to cover the cost of the application. Then calculate the amount of damage required to equal the cost.

Pests and When They are Important

Crop Stage	Possible Pests
Vegetative Stage	
0. Germination	**Mole cricket**, **Ants**, **Rat Control in the Field**
1. Seedling	**Rice whorl maggot**, **Thrips**, **Defoliator**, **Stem borer**, **Green leafhopper**, **Plant hopper**
2. Tillering	**Thrips**, **Defoliator**, **Stem borer**, **Green leafhopper**,

	Planthopper
Minor pests: Aphids, Caseworm, **Black bugs**, **Grasshoppers**, Mealybugs, **Gall midge**, **Hispa**	
Reproductive Stage	
3. Stem elongation	**Defoliator**, **Stem borer**, **Green leafhopper**, **Planthopper**
4. Panicle initiation to booting	**Stem borer**, **Green leafhopper**, **Planthopper**
5. Heading	**Planthopper**, **Rice bug**
6. Flowering	**Planthopper**, **Thrips**, **Rice bug**
Minor pests (reproductive phase): Greenhorned caterpillars, Skippers	
Mature grain stage	
7. Milky grain stage	**Planthopper**, **Rice bug**
8. Dough grain stage	**Rice bug**
9. Mature grain	
Minor pests (Reproductive phase): Panicle mite, Flower thrips	
Storage pests	**Rice Weevil**, **Rust-red flour beetle**, **Lesser Grain Borer**, **Rats**, **Rat Control in Storage**, **Birds**
Minor pests: **Angoumois Grain Moth**, Cigarette or Tobacco Beetle, Flat Grain Beetle, **Saw-toothed Grain Beetle**	

Damage Symptoms and Likely Pests Involved

Damage Symptom	Likely Pest Involved
Poor stand establishment	**Mole cricket**, **Rice seedling maggot**, ants
Leaf damage: Burning and twisting of young leaves	**Rice whorl maggot**, **Thrips**
Leaf damage: Leaves drying and dying	**Planthopper**
Leaf damage: Cut leaves	**Defoliators**
Deadhearts	**Stemborers**, **Rice seedling maggot**
Dry dead circles of crop (Hopper burn)	**Planthopper**
Tungro - plants stunted	**Green leafhopper**
Whiteheads	**Stemborers**
Grain damage	**Rice bug**, **Thrips**
"Onion leaf", silver shoot	**Gall midge**

List of Insecticides and Pests Reportedly Controlled

Insect code: SP = soil pests; RWM = rice whorl maggot; T = Thrips; D = Defoliators; SB= Stem borer; GLH = Green leafhopper; GM = Gall midge; PH = planthopper; RB = Rice bug

Product	Primary pests controlled							
	SP	RWM	T	D	SB	GLH	PH	RB

BPMC also known as Fenobucarb (Baycarb, Hopcin)	Y		Y			Y	Y	
BPMC + Alphacypermethrin (Fastac R)	Y		Y	Y		Y	Y	Y
Buprofezin (Applaud)						Y	Y	
Carbaryl (Sevin)			Y	Y		Y		
Carbofuran (Furadan)	Y	Y	Y	Y	Y			
Cartap HCl (Dimotrin)				Y	Y	Y	Y	
Chlorpyrifos (Lorsban)			Y		Y	Y		Y
Chlorpyrifos + BPMC (Brodan)			Y	Y		Y		
Cypermethrin (Cymbush)				Y		Y	Y	Y
Deltamethrin (Decis)							Y	Y
Diazinon (Diazinon)					?	Y		
Dimethoate (Roxion, Perfecthion)			Y		Y	Y		
Fipronil (Regent, Ascend)				Y	Y		Y	
Isoprocarb (MIPC)						Y	Y	
Malathion (Malathion)			Y			Y		Y
MTMC + Phenoate MTMC = Metolcarb (Carbophen)						Y		
Triazophos (Hostathion)		Y	Y	Y	Y	Y		

IPM Levels

IPM critical levels, management options and period when potentially problematic.

Pest	Critical level	Management option	Critical period
Mole cricket	No levels	Flood field	Emergence only
Seedling maggot	No levels	Flood field	Emergence only
Rice whorl maggot	No levels	Drain field	Seedling only
Defoliators	>25% leaves damaged or 10 leaves/hill	Don't spray for first 30-40 days	Seedling to stem elongation
Thrips	> 25% leaves damaged	Flood field	Emergence to tillering only
Stemborers	10% hills affected (1 panicle/hill) (4 egg masses/hill)	-	Panicle intitation to booting
Plant hoppers	15 nymphs/hill	-	Seedling to milky grain
Green leaf hopper	5 nymphs/hill if tungro present 15 nymphs/hill if no tungro	-	Seedling to panicle initiation

Rice bug	>1 bug/2 hills	-	Pre-flowering spikelets to soft dough

IPM Field Scouting Procedure

Sampling procedure: Recommendations same for Indica and Japonica.

1. Sample size: 10 hills
2. Hill selection: randomly on diagonal, zigzag or straight sampling pattern across field.
3. Hill monitoring:
    - Hoppers - each hill is tapped with a stick - the insects that fall into the water are identified and counted.
    - Defoliators, rice bug: number/hill is counted
    - stemborer (dead hearts, larvae, adults, and egg masses) Number of each/hill is counted
    - Eggs: Egg masses of whorl maggot, defoliators and stemborers are counted.

4. Insect stage identification: Instar stage for stemborers and defoliators is noted
5. Crop stage: The growth stage of the plant is noted.

Converting Active Ingredient into Product

- Link to **Product Calculator**
- Calculated examples: To convert active ingredient to product (always check units)
- Product required = rate of active ingredient (a.i./ha)/(active ingredient in product) (a.i./l)

Example
- Apply Pretilachlor at 300 g a.i./ha
- Sofit = 300 g pretilachlor/l
- = 300 (g a.i./ha)/300 (g a.i./l) = 1 l Sofit

Alternate method
- Product required = rate of active ingredient (a.i/ha) * 100/(percent active ingredient in product)

Example
- Apply Pretilachlor at 300 g a.i./ha
- Sofit = 300 g pretilachlor/l = 30% a.i.
- = 300 (g a.i./ha) * 100 /30 a.i. = 1000 g sofit/ha = 1 l Sofit (assume 1 g = 1 ml)

To estimate the product to add per tank and number of tank loads required
- Product/tank
- = product (per ha) * tank capacity/Total liquid volume per ha to apply (water + agro-chemical)

Example
- Total volume of product/ha = 1 l

- Spray calibration = 150 l/ha
- Sprayer capacity = 16 l
- Product/tank = 1 * 16/150 = 107 ml/tank

Number of tank loads required per field
= Total liquid volume to apply (water + agro-chemical) (l per ha) * Area (ha)/Tank capacity (l)

Example
Calibration = 150 l/ha
Tank capacity = 16 l
Tanks/ha Area to apply = 0.6 ha
Number of tanks loads = 150 (l/ha) * 0.6 ha/16 (l/tank) = 5.625

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- Thomson, W.T. 1994. Agricultural Chemicals. Book I. Insecticides. 1994-95 Revision. Thomson Publications.Fresno, Ca.
- Tomlin, C.D.S. 1997. The Pesticide Manual, Eleventh Edition. British Crop Protection Council.

Major Pests

Black Bug

Scotinophara coarctata (F.)

- Significance: Generally a minor problem – except in some localized areas, rarely an economic problem. Dormant during dry weather.
- Growth stages when a problem: Throughout crop cycle when plant sap flowing.
- Damage symptoms: Area around feeding holes turn brown resembling blast lesions. Leaves may dry and roll longitudinally. Deadhearts (DH) and whiteheads (WH) are common damage symptoms.
- Economic threshold levels: 5 or more nymphs or adults per hill.
- Life cycle: 28-35 days
- Mechanism of damage: Suck sap
- Control options:
    - Depending on the area and situation, control is generally not required
    - Adults are highly attracted to light traps, but burning and killing the light-trap collected bugs is necessary.

Serious pest in Mindanao and Palawan (Philippines). Considered an emerging pest problem.

Defoliators

IPM - recommends no spray for defoliators for the first 30 days in transplanted and first 40 days in direct seeded crops (includes Rice leaf folders, Armyworm, Greenhorned catepillar, Green semilooper, Green hairy caterpillar).

- Significance: Rarely a problem; Generally present
- Appearance: Bugs and catepillars
- Pictures - **Caseworm**, **Rice leaf folders**, **Cutworm/Armyworm**, **Greenhorned catepillar**, **Green semilooper**
- Growth stages when a problem: Seedling to stem elongation (1-3)
- Damage symptoms: Whitish stripes on leaf and/or defoliation
- Economic threshold levels: >25% leaf damage or 10 leaves/hill
- Life cycle: 30-60 days
- Mechanism of damage: Scraping of leaf tissue and/or defoliation
- Control options:
  - Control generally not required - don't spray for 30 days after transplanting or 40 days after direct seeding
  - Triazophos EC (0.4 kg a.i./ha = 1.0 l Hostahion/ha)
  - Chlorpyrifos + BPMC (0.4 kg a.i./ha = 1.27 l Brodan/ha)
  - Cartap HCl (0.25 kg a.i./ha = 0.5 l Dimotrin/ha)
  - Fipronil (50-150 g a.i./ha = ? Regent or Ascend)
  - Carbaryl WP (0.75 kg a.i./ha = 0.88 l Sevin/ha)
  - Carbofuran 3 G (1 kg a.i./ha = 33.3 kg Furadan/ha)
  - BPMC + Alphacypermethrin (0.8 l Fastac-R/ha)
- Comments: Damage rarely sufficient to warrant control

Asian Gall Midge

Orseolia oryzae (Wood-Mason)

- Significance: Generally a minor problem – except in some localized areas.
- Appearance: Adult like a small mosquito: **Picture**
- Growth stages when a problem: Seedling to panicle initiation.
- Damage symptoms: Tubular gall resembling an onion leaf. May be long like a leaf or short and diffcult to see. Tillers with galls do not produce panicles.
- Economic threshold levels:
- Life cycle: 28-32 days
- Mechanism of damage: Gall midge larvae feeding at the growing point.
- Control options:
    - Control generally not required
    - Remove alternate hosts during fallow (e.g., wild rice)
    - Use resistant varieties
    - Adults are highly attracted to light traps
    - Sprays are typically less effective because the larvae is within the gall or plant.
    - Granules in water are usually better. e.g., Carbofuran 3G (1 kg a.i./ha = 33.3 kg Furadan/ha
- Comments: Adults are weak fliers and thus distribution is typically localized.

Green Leafhopper

Nephotettix spp.

- Significance: Primarily a problem in the spread of Tungro (a viral disease that stunts plants)
- Appearance: **Picture** (Also see **Zigzag leafhopper**)
- Growth stages when a problem: Seedling to panicle initiation (1-4)
- Damage symptoms: Tungro (plant virus) causes stunting, reduced tillering, of the plant, leaves light yellow to orange-yellow.
- Economic threshold levels: 5 per hill. If tungro is present, even 2 can destroy a crop.
- Life cycle: 23-30 days
- Mechanism of damage: virus spread or direct sucking
- Control options:
    - Control generally not required (only if Tungro present.)
    - BPMC EC (0.4 kg a.i./ha = 0.8 l Baycarb or Hopcin/ha)
    - BPMC + Alphacypermethrin (0.8 l Fastac-R/ha)
    - Cartap HCl (0.25 kg a.i./ha = 0.5 l Dimotrin/ha)
    - Isoprocarb (0.5-0.75 kg a.i./ha = ? kg MIPC /ha)
    - MTMC + Phenoate (0.9-1.2 kg a.i./ha = ? kg Carbophen/ha)
    - Various others (See list of Insecticides)
- Comments: Direct damage from GLH is rarely sufficient to warrant control. However, control may be required if Tungro is prevalent.

Rice Hispa

*Dicladispa armigera (*Olivier)

- Significance: Generally a minor problem – except in some country areas. Rarely an economic problem
- Appearance: **Picture**
- Growth stages when a problem: Seedling until maturity.

- Damage symptoms: Narrow white areas on a leaf. If severe, can look like hopper burn.
- Economic threshold levels:
- Life cycle: 21-28 days
- Mechanism of damage: Adults and grub feed on the upper leaf surface.
- Control options.
    - Control generally not required

Mole cricket

Gryllotalpa orientalis (Burmeister)
Best controlled through flooding.

- Significance: Rarely a problem and then only in dry unflooded fields
- Appearance: Cricket with enlarged front legs. **Picture**
- Growth stages when a problem: Seedling to tillering (1-2)
- Damage symptoms: Dead seedlings, bare spots in field
- Economic threshold levels: Rarely a problem in paddy; levels do not exist, as pest can not be scouted
- Life cycle: Approximately 6 months
- Mechanism of damage: Eat seeds and young roots
- Control options:
    - Control generally not required
    - Flood field
    - Baits (rice bran + insecticide)
    - Carbofuran 3G (1 kg a.i./ha = 33.3 kg Furadan/ha)
- Comments: Check roots for damage to confirm the presence of mole cricket.

Planthopper

- Planthopper (especially Brown Planthopper - sometimes Whitebacked)
- Significance: Typically a secondary problem that arises due to early spraying
- Appearance: Pictures - **Brown planthopper**; **Whitebacked planthopper**
- Growth stages when a problem: Seedling to Milky grain stage (1-7)
- Damage symptoms: Yellowing and rapid drying of the plant generally in circular patterns - Hopper burn
- Economic threshold levels: 15 per hill
- Life cycle: 21-33 days
- Mechanism of damage: sucking on plant vascular system
- Control options:
    - Control generally not require
    - (becomes a problem when early sprays kill beneficials)
    - Buprofezin (0.05 kg a.i./ha = 200 g Applaud/ha)
    - BPMC EC (0.4 kg a.i./ha = 0.80 l Baycarb or Hopcin/ha)
    - BPMC + Alphacypermethrin (0.8 l Fastac-R/ha)
    - Deltamethrin (0.015 kg a.i./ha = 1 l Decis/ha)
    - Cartap HCl (0.25 kg a.i./ha = 0.5 l Dimotrin/ha)
    - Fipronil (50-150 g a.i./ha = ? Regent or Ascend)
    - Carbaryl WP (0.75 kg a.i./ha = 0.88 l Sevin/ha) (doubtful efficacy)
    - Isoprocarb (0.5-0.75 kg a.i./ha = ? kg MIPC /ha)

- Comments: Typically a secondary pest induced as a result of early spray applications.
- Ad K to reduce planthopper damage (Jahn, et al. 2001).

Rice Bug

Leptocorisa oratorius (F.)
Leptocorisa chinensis (Dallas)
Leptocorisa acuta (Thunberg)

- Appearance: (An odor is often emitted indicating their presence) **Picture**
- Growth stages when a problem: Pre-flowering spikelets to milky grain stage
- Damage symptoms: Withered and discolored grain, unfilled grain, chalky grain
- Economic threshold levels: > 1 bug/2 hills at pre-flowering spikelet to flowering stage
- Mechanism of damage: Sucking on developing grains
- Management options:
  - Remove weeds from fields and surrounding areas
  - Level fields and apply fertilizer evenly to encourage synchronous development of rice
  - Collect rice bugs with nets before flowering stage
  - Attract rice bugs to traps baited with spoiled fish, decaying meat, or chicken manure
  - Do not apply insecticides before the economic threshold is reached. It is normally not necessary to spray for rice bugs. If spraying is deemed necessary then it should be done in the early morning or late evening when rice bugs are in the canopy.

- Insecticides:
  - carbaryl WP (0.75 kg a.i./ha = 0.88 l Sevin/ha)
  - BPMC + alphacypermethrin (0.8 l Fastac-R/ha)
  - malathion (1.0 kb a.i./ha = 1.75 l Malathion/ha)
  - beta-cyfluthrin
  - cypermethrin
  - fenthion
  - fenitrothion
  - acephate

Rice Seedling Maggot

- Significance: Generally minor pest - only significant in Upland or Lowland without water
- Appearance: no photo available
- Growth stages when a problem: Seedling to tillering (1-2)
- Damage symptoms: Dead hearts, missing hills. Looks different from stem borer damage.
- Economic threshold levels: Rarely a problem in paddy
- Life cycle:
- Mechanism of damage:
- Control options:

- Control generally not required
- Flood field

Rice Whorl Maggot

Hydrellia philippina
Problem reduced by draining field.

- Significance: Rarely an economic problem; widespread; Incidence greater in wet season
- Appearance: Translucent larvae found within early rice tillers **Picture**
- Growth stages when a problem: Seedling to tillering (1-2)
- Damage symptoms: Distortion and whitening/yellowing of margins of young leaves
- Economic threshold levels: Not considered a problem at most levels of damage
- Life cycle: 4 weeks (approximately)
- Mechanism of damage: Rasp growing points and margins of developing leaves
- Control options:
  - Control generally not required
  - Drain/dry field
  - Triazophos EC (0.4 kg a.i./ha = 1.0 l Hostahion/ha)
  - Carbofuran 3G (1 kg a.i./ha = 33.3 kg Furadan/ha)
- Comments: RWM can only be controlled prophylactically - when damage is visible, the pest has already left the crop.

stem borer

Chilo suppressalis

- Significance: Stemborers are the most pervasive insect pest of rice. The extent of yield loss due to damage is still uncertain
- Appearance: Adult moths and larvae in stem **Picture**
- Growth stages when a problem: Seedling to panicle initiation (1-4)
- Damage symptoms: Dead heart (Stunted or dead tillers); Whitehead (Unfilled panicles)
- Economic threshold levels: 10% of hills affected; 4 egg masses per hill (at booting stage) (Plants seem to be able to compensate up to 1 tiller per hill damaged - if other management is adequate)
- Life cycle: 40-70 days (depending upon species)
- Mechanism of damage: Larvae feeding within stems sever pant vascular system.
- Control options: Prophylactic is the primary option
  - Carbofuran 3G (1 kg a.i./ha = 33.3 kg Furadan/ha)
  - Cartap HCl (0.25 kg a.i./ha = 0.5 l Dimotrin/ha)
  - Fipronil (50-150 g a.i./ha = ? Regent or Ascend)
  - Chlorpyrifos EC (0.4 kg a.i./ha = 1.33 l Lorsban/ha)
  - Dimethoate (0.4 kg a.i./ha = 0.93 l Roxion/ha)
  - Triazophos EC (0.4 kg a.i./ha = 1.0 l Hostahion/ha)
- Comments: Once damage is evident, it is too late to treat.

Deadheart caused by stem borer

Thrips

Baliothrips biformis
Limit effects by flooding field.

- Significance: Rarely a problem; Greater incidence in dry season
- Appearance: Minute soft bodied insects **Picture**
- Growth stages when a problem: Seedling to tillering (1-2) and Flowering (6)
- Damage symptoms: Rasped leaves that roll, dry up and turn yellowish to reddish; Thrips can also damage spikelets causing unfilled grains or empty heads
- Economic threshold levels: > 25% of leaves with damage, or 10 leaves per hill damaged
- Life cycle: 22-40 days
- Mechanism of damage: Slash tissue and feed on plant sap
- Control options:
    - Control generally not required.
    - Flood field
    - Dimethoate (0.4 kg a.i./ha = 0.93 l Roxion/ha)
    - BPMC EC (0.4 kg a.i./ha = 0.8 l Baycarb or Hopcin/ha)
    - BPMC + Alphacypermethrin (0.8 l Fastac-R/ha)
    - Various others (See list of Insecticides)
- Comments: Occassionally attack spikelets causing unfilled grains to empty heads.
- Submerge seedlings for 1-2 days.
- Add N.

Pesticides and Major Pests Controlled

Applaud

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Applaud
- Active chemical: Buprofezin
- Insects controlled: **Plant hoppers**; **Green leaf hoppers** (Effective on nymphs only?)
- Recommended application rate: 0.05 kg a.i./ha = 200 (g) Applaud/ha
- Mixtures: no information
- LD50: 2198 mg/kg
- Toxicity class (WHO): III
- Type: Thiadiazine compound
- Insecticide formulation: WP, dust, flowable or granule
- Mode of action: Contact and stomach poison; slow acting, but residual
- Non target effects: Low toxicity to mammals and fish; no adverse effects on beneficial insects
- Produced by: Nihon Nohyaku; AgrEvo; Zeneca

Baycarb or Hopcin

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Baycarb or Hopcin
- Active chemical: BPMC or Fenobucarb
- Insects controlled: **Green leafhopper**; **Plant hoppers**; **Thrips**
- Recommended application rate: 0.40 kg a.i./ha = 0.80 l Baycarb or Hopcin/ha
- Mixtures: Can be mixed with BHC to control stem borers
- LD50: 623 mg/kg
- Toxicity class (WHO): II
- Type: Carbamate compound
- Insecticide formulation: Emulsifiable concentrate (also can come as granules or dust)
- Mode of action: Kills on contact with good residual activity.
- Non target effects: Fish killed at 24-49 ppm
- Produced by: Bayer; Kumiai Chemical Industry Co., Ltd; Mitsubishi Chemical Industries; Sumitomo Chemical Co.

Brodan

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Brodan
- Active chemical: Chlorpyrifos + BPMC
- Insects controlled: **Defoliators**; **Green leaf hoppers**; **Thrips**
- Recommended application rate: 0.40 kg a.i. = 1.27 l Brodan/ha
- Mixtures: Do not mix with alkaline compounds or Sulfur containing fertilizers
- LD50: 96 mg/kg
- Toxicity class (WHO): II
- Type: Organic phosphate

- Insecticide formulation: EC (also comes as WP)
- Mode of action: Primarily by contact activity and as a stomach poison; short residual effect on plants; persists on other surfaces for several weeks
- Non target effects: Toxic to fish and bees
- Produced by: Dow Chemical Co.; Dow Elanco

Carbophen

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Carbophen
- Active chemical: MTMC or Metolcarb + Phenthoate
- Insects controlled: **Green leafhopper**
- Recommended application rate: 0.9-1.2 kg a.i./ha
- Mixtures: Metolcarb - Compatible with other pesticides; Phenthoate - Do not mix with alkaline materials
- LD50: Metolcarb - 268; Phenthoate - 300
- Type: Metolcarb - Carbamate; Phenthoate - Organic phosphate
- Toxicity class (WHO): II
- Mode of action: Metolcarb - Contact, systemic, kills by vapor; Phenthoate - Contact stomach poison
- Insecticide formulation: Metolcarb - EC, WP or dust; Phenthoate - EC or WP
- Non-target effects: Metolcarb - Does not harm spiders which prey on GLH, Low toxicity to fish; Phenthoate - Toxic to bees and fish
- Produced by: Metolcarb - Mitsubishi Kasei Corp and Sumitomo Chemical Co., Japan; Phenthoate - Montedison Italy, and Sumitomo Chemical Co. and Nissan Chemical Industries, Japan

Cymbush

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Cymbush
- Active chemical: Cypermethrin
- Insects controlled: **Defoliators**, **Green leafhopper**, **Plant hopper**, **Rice bug**
- Recommended application rate: 1 l Cymbush/ha
- Mixtures: no information
- LD50: 247 mg/kg
- Toxicity class (WHO): II
- Type: Synthetic pyrethroid
- Insecticide formulation: EC = emulsifiable concentrate
- Mode of action: Contact stomach poison; No systemic effects; Residual on plant
- Non-target effects: Toxic to fish and bees; Non-toxic to birds
- Produced by: Zeneca; FMC; Syngenta; Sumitomo; Cyanamid

Decis

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Decis
- Active chemical: Deltamethrin
- Insects controlled: **Plant hopper**, **Grasshoppers**
- Recommended application rate: 0.015 kg a.i./ha = 1 l Decis/ha,
- Control may be reduced above 35oC
- Mixtures: no information
- LD50: 128 mg/kg
- Toxicity class (WHO): II
- Type: Synthetic pyrethroid
- Insecticide formulation: EC = emulsifiable concentrate, wettable powder or granule
- Mode of action: Contact stomach poison; No systemic effects; 7-21 days residual on plant
- Non-target effects: Toxic to fish, bees and other aquatic life
- Produced by: Zeneca; FMC; Syngenta; Sumitomo; Cyanamid

Diazinon

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Diazinon
- Active chemical: Diazinon
- Insects controlled: **Green leafhopper**; **stemborer**(?)
- Recommended application rate:1 kg a.i./ha = 20 kg Diazinon/ha
- Mixtures: Do not mix with Cu compounds; Compatible with other pesticides
- LD50: 300 mg/kg
- Toxicity class (WHO): II
- Type: Organic phosphate
- Insecticide formulation: Granular
- Mode of action: Contact stomach poison; Long residual effects
- Non-target effects: Ducks and geeses highly susceptible; Toxic to bees
- Produced by: Syngenta

Dimotrin

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Dimotrin
- Active chemical: Cartap-HCl
- Insects controlled: **Stem borers**; **Defoliators**; **Plant hoppers**; **Green leaf hoppers**
- Recommended application rate: 0.25 kg a.i./ha = 0.5 l Dimotrin/ha
- Mixtures: Do not mix with alkaline products; compatible with other insecticides and fungicides
- LD50: 325 mg/kg
- Toxicity class (WHO): II

- Type: Nereistoxin
- Insecticide formulation: Granular, dust or wettable soluble powder
- Mode of action: Contact stomach poison. Some penetration of the plant.
- Non-target effects: Low toxicity to bees.
- Produced by: Takeda Chemical Industries, Japan.

Fastac-R

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Fastac-R
- Active chemical: BPMC + alphacypermethrin
- Insects controlled: **Seedling maggot**; **Rice bugs**; **Defoliators**; **Green leafhopper**; **Plant hoppers**; **Thrips**
- Recommended application rate: 0.8 l Fastac-R/ha
- Mixtures: Can be mixed with some other insecticides
- LD50: 79 mg/kg
- Toxicity class (WHO): II
- Type: Synthetic pyrethroid
- Insecticide formulation: Emulsifiable concentrate (also can come as a wettable powder)
- Mode of action: Contact and stomach poison insecticide. Residual
- Non target effects: Toxic to bees and fish
- Produced by: Shell, FMC, DuPont and Cyanamid.

Furadan

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Furadan
- Active chemical: Carbofuran
- Insects controlled: **Seedling maggot**; **Rice whorl maggot**; **Stem borers**; Nematodes; **Defoliators**; **Thrips**
- Recommended application rate: 1 kg a.i./ha = 33.3 kg Furadan 3G/ha
- Mixtures: Do not mix with alkaline products; Do not apply within 21 days of a propanil application
- LD50: 8 mg/kg (Comes in different formulations of varying classification)
- Type: Carbamate
- Toxicity class (EPA): II (as Furudan G)
- Insecticide formulation: Granular
- Mode of action: Systemic and contact stomach poison. Long residual half life in soil (30-60 days)
- Non-target effects: Toxic to fish, wildlife and bees.
- Produced by: FMC Corp.
- Is being replaced with Fipronil for most uses in rice in the U.S.

Hostathion

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Hostathion
- Active chemical: Triazophos
- Insects controlled: Rice whorl maggot; **Green leaf hoppers**; **Rice whorl maggot**; **Stem borers**; Nematodes; **Defoliators**; **Thrips**
- Recommended application rate: 0.4 kg a.i./ha = 1.00 l Hostathion/ha (Do not apply above 30 degrees C)
- Mixtures: can use with other pesticides
- LD50: 57 mg/kg
- Toxicity class (WHO): Ib
- Type: Triazole
- Insecticide formulation: EC = Emulsifiable concentrate
- Mode of action: Contact and stomach poison; Residual
- Non-target effects: Toxic to bees and fish
- Produced by: Hoeschst Ag; now AgrEvo

Lorsban

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Lorsban
- Active chemical: Chlorpyrifos
- Insects controlled: **Stem borers**; **Rice bugs**; **Green leaf hoppers**; **Thrips**
- Recommended application rate: 0.4 kg a.i./ha = 1.33 l Lorsban/ha
- Mixtures: Do not mix with alkaline products or Sulfur containing fertilizers
- LD50: 96 mg/kg
- Toxicity class (WHO): II
- Type: Organic phosphate
- Insecticide formulation: EC = emulsifiable concentrate
- Mode of action: Contact stomach poison; Short residual effect on plants; persists on solids; no systemic effects
- Non-target effects: Toxic to fish and bees
- Produced by: Dow Chemical (marketed by Dow Elanco)

Malathion

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Malathion
- Active chemical: Malathion
- Insects controlled: **Green leaf hoppers**, **Thrips**, **Rice bug**
- Recommended application rate: 1.0 kg a.i./ha = 1.75 l/ha
- Mixtures: Incompatible with alkaline compounds; Compatible with most insecticides and fungicides
- LD50: 1375 mg/kg
- Toxicity class (WHO): III
- Type: Organic phosphate

- Insecticide formulation:
- Mode of action: Residual on plant if not mixed with alkaline compounds; No residue in soil
- Non-target effects: Toxic to fish and bees
- Produced by: American Cyanamid; Cheminova Agro

MIPC

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: MIPC
- Active chemical: Isoprocarb
- Insects controlled: **Plant hoppers**; **Green leaf hoppers**
- Recommended application rate: 0.5-0.75 kg a.i./ha
- Mixtures: Do not apply 10 days prior to or after a propanil application; Do not combine with alkaline products.
- LD50: 178 mg/kg
- Toxicity class (WHO): II
- Type: carbamate
- Insecticide formulation:
- Mode of action: Stomach poison
- Non-target effects: Toxic to bees
- Produced by: Bayer AG

Regent or Ascend

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Regent or Ascend
- Active chemical: Fipronil
- Insects controlled: **Defoliators**; **Stem borers**; **Plant hopper**
- Recommended application rate: 50-150 g a.i./ha
- Mixtures: unspecified
- LD50: 95 mg/kg
- Toxicity class (WHO): II
- Type: Phenyl pyrazole
- Insecticide formulation: Granular, EC
- Mode of action: Contact residual, moderately systemic
- Non-target effects: Highly toxic to bees,
- Produced by: Rhone Poulenc, France

Roxion, Perfecthion

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Roxion, Perfecthion
- Active chemical: Dimethoate
- Insects controlled: **Green leaf hoppers**; **Thrips**; **Stem borers**

- Recommended application rate: 0.4 kg a.i./ha = 0.93 kg Roxion/ha
- Mixtures: Do not mix with alkaline pesticides; Compatible with some other insecticides and fungicides
- LD50: 225 mg/kg
- Toxicity class (WHO): II
- Type: organic phosphate
- Insecticide formulation: Granular
- Mode of action: Contact residual systemic; short half life on plants and in soil (2-4 days)
- Non-target effects: Toxic to bees
- Produced by: American Cyanamid

Sevin

NOTE: Always follow safe practices and consult the product label and the accompanying instructions before purchasing and using any product.

- Generic name: Sevin
- Active chemical: Carbaryl
- Insects controlled: **Plant hoppers**; **Rice bugs**; **Green leaf hoppers**; **Defoliators**; **Thrips**
- Recommended application rate: 0.75 a.i. = 0.88 l Sevin/ha
- Mixtures: Do not mix with Alkaline products; Compatible with other insecticides and fungicides
- LD 50: 246 mg/kg
- Toxicity class (WHO): II
- Type: Carbamate
- Insecticide formulation: WP = wetable powder
- Mode of action: Contact stomach poison; long residual effect
- Non-target effects: Highly toxic to bees
- Care must be taken at the flowering stage.
- Excessive carbaryl cn induce sterility.
- Produced by: Union Carbide (sold by Rhone Poulenc)

Integrated Control Measures for Rice Pests

Integrated Control Measures of Rice Pests - Principles

- The sections below explain the general effects of the factors on various pests.
- There are nearly always exceptions so local conditions and knowledge have to be considered.
- There are various examples of successful integrated management.
- Often no single practice will suffice but a combination of practices is best.
- The practicality of different practices must be considered in light of the farmers circumstances and the effect of the practice on the farmer's profit and lifestyle. For example, biocontrol agents and species diversity are most abundant in weedy fields. However, not weeding will usually dramatically affect yields and thus reduce farmer profit.

Cultivars

Cultivar choice generally affects pests in the following ways:

Short duration cultivars
- Decrease rat and planthopper populations (as there is less crop time and therefore fewer pest life cycles completed)
- Increases weed damage (as the crop may have less time to recover)

Insect and disease resistant cultivars
- Better growth and therefore reduced weeds
- Less bacterial and fungal diseases due to less insect damage
- Note importance of host plant resistance

Agrochemicals

Pesticides should only be used if they are safe to the environment and the user, and economical. (See section on **Application considerations and safety**).

Pesticides generally affect pests in the following ways:

***Rodenticides* (for rodent control)**
- Weeds grow where rats damage the crop - therefore the use of rodenticides may reduce weeds.

***Insecticides* (for insect control)**
- Reduce pest damage and generally leads to better growth and thus greater competitive advantage against weeds.
- Less bacterial and fungal diseases due to less insect damaged tissue.
- Certain insecticides if improperly used (e.g., excessive early application) will cause an increase in the number of pests (e.g., planthoppers).

***Fungicides* (for fungus control)**
- Reduce weed competitiveness if the crop is healthier.

- Some reduce insect feeding.
- Some may increase hoppers if hopper attacking pathogens are affected.

***Herbicides* (for weed control)**

- Reduce rats attracted to weedy fields
- Reduce some diseases as weed hosts eliminated
- Reduce general species diversity

***Nematicides* (for nematode control)**

- May increase or decrease weeds depending on whether the effect of the nematodes is on the crop or the weeds..

Fertilizer

The general effects of fertilizer are:

High N

- Generally favors rice insect, disease and rodent pests. However, this depends on timing. Can also promote recovery from pest damage (Jahn, et al., 2001).

High Phosphorus and Potassium

- Plants grow well, but may be more attractive to rats.

Split N

- Decreases weeds
- Less fungal and insect growth

NOTE: Balanced nutrition generally means better growth and less disease attack.

Water Management

The general effects of water management on pests are:

Periodic field draining

- Increases rats and weeds
- Increases thrips where dry
- Decreases virus vectors
- Decreases whorl maggot
- Decreases caseworm

Upland fields with no standing water

- Higher weed populations
- Higher nematodes
- Higher fungal disease (especially blast) (due to more dew on the plants)
- Reduced bacterial diseases
- Fewer hoppers

Flooding

- Helps control rats, weeds, fungal diseases and soil inhabiting nematodes
- Increases bacterial diseases
- Generally viral vectors increase
- Decreases thrips

- Increases whorl maggot
- Increases caseworm

Field leveling

- Reduces weed pressures due to the direct effect of the water and due to improved uniformity of crop growth.

Flooding or draining can help control various insect pests (e.g., draining for 3 or 4 days can control caseworm. Flooding seedbed for 1 day can control thrips).

Planting Method

The general effects of planting method on pests are:

Transplanting

- Has no or little effect on pests and biological agents. However, dense rice stands tend to have more humidity-loving pests (e.g., gall midge).
- It does tend to reduce weed problems because of the competitive advantage of the transplanted seedlings

Direct seeding

- Increases weed pressures because of less competition from the crop, but also because hand weeding can be difficult.
- Close plant spacing can provide a favorable environment for hopper vectors of viruses.

Planting Time

The general effects of planting time on pests are:

Early planting

- Diseases and insects tend to be low because of reduced build-up of inoculum or pest populations
- Rats may be more of a problem

Late planting

- Tends to increase pest pressures
- Rats move from harvested plots to late plots.

Wet season planting

- Tends to favor pests due to the large areas sown and the abundance of alternate hosts

Cropping Pattern

The general effects of cropping pattern on pests are:

Staggered planting

- Favors all pests except weeds and nematodes
- Favors biological control
- Pests from maturing fields move to younger fields

Synchronous planting

- Helps with management of rice bugs and other pests.
- Is an effective cultural control method
- Can be problematic to achieve where water supply is variable or poorly controlled

Multiple rice cropping

- Increases pest incidence and the population of biocontrol agents
- Proper pesticide protocols must be followed to conserve biocontrol agents. Early applications in particular are problematic as they tend to result in disproportionate increases in pests.

Stubble Management

The general effects of stubble management on pests are:

Plowing

- is an excellent pest management practice because it removes straw that many pests use as a habitat

Straw burning

- Not recommended due to adverse environmental effects, and the beneficial effects associated with straw incorporation. (Straw however can be difficult for farmers to handle and explains why they often burn or partially burn.)
- When burnt, serves to control stem borers hibernating in stems and rats hiding in the straw.
- Little effect on weeds unless high temperatures are reached to kill surface weed seeds.
- Helps control/prevent some fungal diseases.

Weeding

The general effects of weeding on pests are:

Weeding

- Reduces direct competition with the crop for water, nutrients and radiation.
- Removes rat habitats and alternate hosts of pathogens and insects.
- However, biocontrol agents and species diversity are most abundant in weedy fields, and not all weeds harbor all pests.

References (Integrated Control Measures)

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Biodiversity

Principles of Biodiversity

Exploiting biodiversity for sustainable pest management involves the within-field planting of varieties differing in susceptibility to the diseases or pests. The principles behind biodiversity for plant disease management are:

- Diverse varieties can provide complementary disease resistance and other positive agronomic effects
- Mixtures of plant genotypes can reduce disease spread
- Mixed pathogen populations may lead to induced resistance
- Diverse varieties may reduce the selection pressure on the pathogen and slow down pathogen evolution (thus increasing the number of years that a variety can remain resistant).
- These factors can lead to reduced spray requirements and increased yield

Example Application - China and Blast

Situation
Farmers in Yunnan province, China practice within-field planting of varieties with different susceptibility to diseases to control rice blast. The rice varieties used are: 1) a tall glutinous (sticky) rice that is popular with consumers, commands a higher price, but which is susceptible to blast, and 2) a shorter blast resistant high-yielding hybrid.

Varieties were transplanted according to local practices, namely:
One row of glutinous rice is planted for every four rows of the hybrid indica rice according to the following diagram:

X X O X X X X O X X, where "X" represents hybrid rice and "O" represents glutinous rice
X X O X X X X O X X

The spacing between plants (cm) is:
X 15 X 15 O 15 X 15 X 30 X 15 X 15 O 15 X 15 X 30 X etc.

Some farmers use a spacing of 1:4 (glutinous:hybrid), while others used 1:6.

Results

- Disease susceptible glutinous varieties planted in mixtures with resistant varieties had 89% higher yields and 94% less blast damage when compared to monoculture cropping (on a per hill basis).
- The use of biodiversity was so successful that fungicidal sprays were reduced from 3 or more to none over the two years of the project.
- During the 2000 crop season, 42,500 hectares were planted to mixture in Yunnan province, 9 other provinces in China began testing the technology.

Major Considerations for Success

- Identifying mixture components: Diversity per se would not work as not all variety mixtures provide functional diversity to a given plant pathogen population. For optimum results, it was necessary to screen for variety combinations that provided functional diversity against a given plant pathogen population.
- Planting and harvesting: Rice in China is typically hand transplanted and harvested allowing easy separation of the two types of rice for threshing and marketing purposes.
- There are cases where varieties of similar height, maturity and quality are mixed for enhancing biodiversity (e.g., wheat in the Pacific Northwest of USA).

Beneficial Insects

Introduction to Beneficial Insects

- Not all insects are pests - There are rich communities of beneficial insects, spiders and diseases that attack insect pests of rice. Without these beneficials, insect pests would multiply so quickly, they would completely consume the rice crop.
- Pests have high reproductive rates to offset the naturally high mortality rates they face in nature. For example, it is not unusual for a pest like brown planthopper to have 98-99% mortality. If such mortality rates do not happen then a pest population explosion can occur.
- Natural enemies also have enemies of their own. For example, most predators are cannibalistic, a behavior that ensures that in the absence of prey, some will survive.
- Indiscriminate use of pesticides can easily disrupt the natural balance between insects pests and their natural predators. Thus, although insecticides may be needed in some cases, they must be used judiciously in order to maximize the effect of the natural control agents.

Predators

- Predators are often the most important group of biological control organisms in rice.
- Many species of predators conspicuous and are sometimes confused with pests.
- Predators occur in almost every part of the of the rice environment.
- Predators tend to be generalist feeders and often attack other beneficial species when other food is scarce. It is important to realize that a few insect pests occurring at levels which cause no economic damage are helpful for they provide food to maintain populations of beneficial species at levels which can prevent damaging pest outbreaks.
- It is extremely costly to mass rear predators for release in rice fields. Since there are already many predators in the fields, they should be conserved by limiting broad-spectrum insecticide use, or by applying insecticides which are selectively toxic to pests but not to predators.

Examples of predators include: **Lady beetles**, **Ground beetle**, **Crickets**, **Grasshoppers**, **Water strider**, **Assassin bugs**, **Damselflies**, **Earwigs**, **Ants**, Wasps (**anagrus**, **cotesia**, **eulophus**, **gonatocerus**, **gryon nixoni**, **opius barrioni**, **platygaster oryzae**, **telenomus rowani**, **temelucha**, **trichoma**) and Spiders (**long-jawed**, **orbweb**, **lynx**)

Parasites

- Parasites may attack eggs, larvae, nymphs, pupae or adults of the host.
- Parasites lay their eggs either in or near the host. When a parasite egg hatches and the immature parasite develops, the host usually stops feeding and soon dies.
- Parasites are generally more host specific than predators. That is why, except for the larger, brightly colored species, they are often overlooked.
- Unlike predators, parasites can find their hosts even when host density is low.
- In general, most rice fields have a rich community of parasites that help keep pest populations at economically insignificant levels.
- Mass rearing of parasites is usually very expensive.
- Parasites should be conserved by limiting broad-spectrum insecticide use, or by applying insecticides which are selectively toxic to pests but not to parasites.

Examples of parasites include: **Big headed flies**, Wasps (**anagrus**, **cotesia**, **eulophus**, **gonatocerus**, **gryon nixoni**, **opius barrioni**, **platygaster oryzae**, **telenomus rowani**, **temelucha**, **trichoma**), and some other species of flies.

Pathogens

- Various pathogenic microorganisms can infect and kill insect pests of rice.
- Of the pathogens, fungi are by far the most important especially on various leafhoppers and planthoppers. For example, fungal outbreaks can kill up to 90-95% of a population of brown planthoppers.
- Virus and fungi can often control caterpillar pests.
- Diseases of pests can often be mass produced at a low cost in a liquid or powder form that can then be sprayed on to the crop.

Examples of pathogens include: Fungus (**beauveria**, **cordyces**, **hirsutella**, **metarhizium**, **zoophthora**) and Virus diseases and Bacteria.

Most Commonly Seen Beneficials

While there are dozens of potentially beneficial predators, parasites and pathogens, just a few tend to be observed in the field.

Predators	Parasites	Pathogens
Lady beetles	Wasps (**anagrus**, **cotesia**, **eulophus**, **gonatocerus**, **gryon nixoni**, **opius barrioni**, **platygaster oryzae**,	Rarely observed

	telenomus rowani, temelucha, trichoma)	
Ground beetles	**Flies**	
Water bugs	Others rarely observed	
Dragon flies		
Damsel flies		
Spiders • **Wolf** • **Long jawed** • **Lynx**		

Major Pests and the Most Important Beneficials

While there are dozens of potentially beneficial predators, parasites and pathogens just a few tend to be important in the field. Here we list the major insect pests and the most common and important beneficiaries.

Primary pests	Most common and important Predators	Most common and important parasites	Most common and important pathogens
Pests of wide spread importance			
Yellow stem borer	**Long-horned Grasshopper** (*Conocephalus longipennis*) **Cricket** (*Metioche vittaticollis; Anaxipha longipennis)*	**Wasp** (**Telenomus rowani**) (*Trichogramma japonicum*)	**Fungus** (*Cordyces* sp.) (**Beauveria bassiana**)
GLH (especially important as a vector of Tungro)	**Cricket** (*Metioche vittaticollis; Anaxipha longipennis)* **Damselfies** (*femina femina*)*Agriocnemis* **Long-horned Grasshopper** (*Conocephalus longipennis*) **Wolf spider** (*Pardosa pseudoannulata*)	**Wasp** (**Gonatocerus spp.**) (*Anagrus* spp.) **Big-headed flies** (*Tomosvaryella* spp.)	**Fungus** (**Beauveria bassiana**) (**Hirsutella citriformis**)
Rice bug	**Assassin bug** (*Rhinocoris* spp.) **Long-horned Grasshopper** (*Conocephalus longipennis*)	**Wasp** (**Gryon nixoni**)	**Fungus** (**Beauveria bassiana**)
Pests of more localized importance			
BPH (Especially Cambodia, Thailand, Indonesia and Philippines)	**Cricket** (*Metioche vittaticollis; Anaxipha longipennis)* **Carabid or ground beetles** (*Ophionea* spp.) **Damselflies** (*Agriocnemis femina femina*) **Long-horned Grasshopper** (*Conocephalus longipennis*) **Wolf spider** (*Pardosa pseudoannulata*)	**Wasp** (**Anagrus spp.**) (**Gonatocerus spp.**)	**Fungus** (**Hirsutella citriformis**) (**Beauveria bassiana**)
Defoliators Armyworm Leaffolders Ricewhorl maggot	**Ants** (*Solenopsis geminata*) **Carabid or ground beetles** (*Ophionea* spp.) **Cricket** (*Metioche vittaticollis; Anaxipha longipennis)* **Damselflies** (*Agriocnemis* spp.) **Flies** (*Ochthera sauteri*)	**Tachinid flies** (*Palexorista* spp.) **Wasp** (**Cotesia spp**.) (**Opius barrioni**) (**Trichomma cnaphalocrosis**)	**Virus** (**Nuclear polyhedrosis virus or NPV**) **Fungus** (**Beauveria bassiana**) (**Metarhizium anisopliae**) (**Zoophthora**

	Waterstriders (*Limnogonus/Gerris*)	(**Temelucha spp.**)	**radicans**)
Gall midge (Especially Indonesia, Thailand, Cambodia, Laos & India)	**Long-jawed spider** (*Tetragnatha* spp.)	**Wasp** (**Platygaster oryzae**)	
Hispa beetle (esp Bangladesh)	**Orbweb spider** (*Argiope catenulata*)?	**Wasp** (**Trichogramma sp.**) (*Eulophus* sp.)	
Black bug (Philippines: especially in Mindanao and Palawan, but not found in Luzon; Cambodia; Thailand; Vietnam; Indonesia & Malaysia)	**Ants** (*Solenopsis geminata*) **Assassin bug** (Stenonabis tagalica)?	**Wasp** (**Telenomus *triptus***)	**Fungus** (**Beauveria bassiana**) (**Metarhizium anisopliae**)
Thrips (usually a problem in greenhouses)	**Long-jawed spider** (*Tetragnatha* spp.)? **Lady beetle** (*Micraspis* spp.) (*Harmonia octomaculata*)	?	?

Predators Often Confused with Pests

The following table shows the primary beneficials that may be confused with pests.

Beneficial	Pest
Predatory Crickets	**Crickets**
Meadow Grasshoppers	**Grasshoppers**
Assassin bug	**Rice bug**
Parasitic wasps (**anagrus**, **cotesia**, **eulophus**, **gonatocerus**, **gyron nixoni**, **opius barrioni**, **platygaster oryzae**, **telenomus rowani**, **temelucha**, **trichoma**)	Gall midge, gnats, mosquitos
Immature **lady bug**	**Defoliators** (**caterpillars**)

Disease Management

Principles of Disease Effects and Management

Diseases are becoming increasingly important as yield levels are raised and higher levels of nitrogen are applied.

Disease can affect yields through either:

1. reduction of photosynthetic area - thus late infestations around booting will likely affect yields, or
2. reduction on photosynthate flow in the plant (equivalent to blocking of the plant's pipes).

Common Diseases and their Symptoms

Seven of the most common diseases

Disease	Stage important*	Symptoms	Season important	Factors favoring infection
Tungro (Viral)	1-3	• Stunted plants, reduced tillering • Leaves - yellow to yellow orange	Periodic	• High population of GLH vectors; • Presence of infected plants
Blast	1	• Leaf lesions - grey centers large in the middle tapering to ends (symptoms are similar to Helminthosporium leaf spot) • also attacks nodes on stem (do not confuse with rat damage • panicle attack (neck rot) can be confused with stemborer damage	• Mostly wet Cloudy skies, • frequent rain and drizzle	• High fertility; • High relative humidity
Sheath blight	2 (Max)	Leaf sheath - Greyish green lesions between	Periodic	• High temperatur

		the water and the leaf blade		e and humidity, • High levels of N, • High yield levels
Bacterial leaf streak	1-9	Leaves - water soaked streaks running along the length of the leaf turn yellow to orange.	Wet	High temperature and humidity
Ragged stunt (Viral)	1-9		Periodic	High population of vector (BPH)
Sheath rot	5-9		Periodic	High temperature and humidity

***** "Stage important" corresponds to the following values:***

Vegetative:

0. Germination
1. Seedling
2. Tillering
3. Stem elongation

Reproductive

4. Panicle initiation to Boot
5. Heading
6. Flowering

Ripening (30 days):

7. Milk
8. Dough
9. Mature

Reference: Mueller, K.E. 1970. Field Problems of Tropical Rice. IRRI. 1980 Fifth printing.

Control Options

While **resistant varieties** and other practices (see **Integrated Control Measures of Rice Pests**) are preferred, sometimes spraying may be considered necessary. This should be done only when diseases are at either moderate or severe levels.
Sample size: 10 hills

Diseases

- Tungro (Primary concern)
- Ragged stunt
- Others: Blast, Bacterial leaf streak, Sheath rot, Bacterial leaf blight

Infection ratings

- Light 0-30% infection
- Moderate 31-60% infection
- Severe >61% infection

NOTE: Once Sheath blight is established in high fertility crops, it can be difficult to control.

Products Commonly Used

Click here to access a **Product Calculator** to estimate the amount of product required to apply a given rate of active ingredient to a defined area.

Disease	Vector/Organism	Control measure
Tungro (Viral)	Leaf hoppers (GLH, ZLH)	• See **GLH** • Remove diseased plants • See **Insect management**.
Blast	Fungal	Benlate (0.6 kg/ha) or Hinosan (1.67 kg/ha)
Sheath blight		Benlate (0.6 kg/ha) or Hinosan (1.67 kg/ha) prophylactic: Apply 4 days after last N application around PI Apply 4-5 days before booting.
Bacterial leaf streak	Bacteria	None
Bacterial leaf blight	Bacteria	None
Ragged stunt (Viral)	Brown planthopper	See **BPH** and **Insect management**.
Sheath rot	Fungal	Benlate (0.6 kg /ha)
Sclerotium rolfsii	Fungal	Brasicol (a PCMB fungicide)

NOTE: Some recommend Validamycin and Rovral (Iprodione) if available for Sheath blight.

Snails, Rats, and Birds

Potential Problems During Crop Establishment

Establishment method	Snails	Rats	Birds	Weeds
Transplanting	Yes	Less	No	Somewhat
Wet direct seeded	Yes	Yes	Yes	Yes
Dry direct seeded	Limited	Yes	Yes	Major

Pests during crop establishment provides the user with information on how to manage the problems of snails, rats, birds and weeds during crop establishment.

Snails

Golden Apple Snail control

Critical times for Golden Apple Snail control:

- Transplanted - First 10 days.
- Wet seeded - First 21 days.
- After this, the crop growth rate is typically greater than the rate of snail damage.

Water management

- Snails focus where there is standing water
- If transplanted - flash flood fields for first 15 days
- If direct seeded - flash flood fields for first 21 days.

Canalettes

- Install canalettes before planting in both wet and dry conditions to facilitate field drainage.

Handpicking and egg crushing

- Crush egg masses and/or hand pick snails - some products can be used as an attractant - e.g., Papaya.

Limit migration along canals

- Put netting over water inlets (this has some control, although many snails simply bury themselves and "hibernate" in the soil as the soil dries.
- Plant older seedlings or plant multiple seedlings/hill.
- Plant on small ridges.

Chemical

- Apply products such as Snaikill or Porsnail (Methaldehyde) or Bayluscide (Niclos amide) can be applied to canalettes, or water pockets where snails are active. Always ensure **safe application**.

- Chemical can also be applied to the entire flooded field. Always ensure **safe application**.

Product	a.i.	a.i./ha	product/ha
Porsnail	Metaldehyde	0.75	1.0
Snailkil (granule)	Metaldehyde	0.12	2.0
Bayluscide	Niclos amide		1.0

Rat Control in the Field

Rat control can be based around four activities, namely:

- General hygiene
- ABS (Active Barrier System), and
- Flame throwers
- Baiting stations

1. General hygiene - General hygiene about the fields and buildings is probably the most important in controlling rats.
    - Cover seed in direct seeded plots
    - Limit habitat and food sources

      - Clean bunds and levees
      - Keep irrigation and drainage canals clean
      - Cover burrows (and/or place treated grain near such)
      - Destroy and rebuild levees (to destroy burrows)
      - Reduce food supplies around buildings

2. ABS (Active Barrier System) - The ABS consists of a system of low plastic (e.g., plastic sheeting) or CTBS (Community Trap Barrier System) walls with holes - behind the holes are one-way traps. Traps should be checked regularly (e.g., daily) and trapped rats disposed of. The principle is that the rat will first look for a way through the plastic wall before going over.

    ABS specifications:

- Plastic height: 40 cm above ground. At the base, 20 cm of plastic are laid flat on the ground and covered with soil.
- Post spacing: 2m
- Post support: Posts are 20 cm in the soil and "tied" together by wire.
- Trap spacing: 15-25m
- When installed: The ABS is best installed about 1 week after transplanting - before damage occurs, and before the canopy closes and rats are already in the canopy.
- Spacing from bund: 50cm (to avoid rats jumping barriers).

3. Flame throwers - Flame holes and have beaters available to kill any escaped rats.

4. Baiting stations - (e.g., 1:19 Racumin:milled rice)

   Note: Baited rats can be a problem to other animals. Livestock (e.g., chickens) must be kept safely away from baited grain.

   - Stations - can be rectangular galvanized iron or an old small plastic container (e.g., from car oil - remove ends and lay in rice grain treated with a recommended rat bait)
   - Perimeter positioning: position traps around the field perimeter. Take care about stary livestock (e.g., poultry eating grain).
   - Field: Place traps (around 3 per 100 m of levee on alternating sides). A further three can be placed in the field across the diagonal. A marker with red paint on top shows the location. Place traps if damage becomes apparent.

Rat Control in Storage

Rodents are characterised by their teeth. They have a pair of incisor teeth in the upper and lower jaws. The incisors are curved inwards and have an extremely hard anterior coating. The softer inside layer is worn down much more rapidly than the hard, outer layer. This means that the teeth are continually kept sharp, enabling them to damage even materials such as masonry and electric cables. The incisors do not stop growing. This means that the animals are forced to gnaw steadily in order to wear them down.

The three most important rodent species are:

- Black rat or House rat *(Rattus rattus)*
- Norway rat or Common rat *(Rattus norvegicus)*
- House mouse *(Mus musculus)*

There are also a number of species which are of great importance in specific regions:

- Multi-mammate rat *(Mastomys natalensis)* in Africa and the Middle East;
- Bandicoot rat *(Bandicota bengalensis)* in Southern and South East Asia;
- Pacific rat *(Rattus exulans)* in South East Asia, also occurring in Southern Asia

Rats and mice cause losses in a number of ways:

- **Feeding on stored produce**

Rats eat an amount of food equivalent to 7% of their body weight daily, i.e. a rat with a body weight of 250 g will eat around 25 g daily, amounting to 6.5 kg of grain a year. Mice eat a daily amount equivalent to around 15% of their body weight, i.e. a mouse weighing 25 g will eat between 3 and 4 g a day, amounting to 1.4 kg of grain a year. Besides feeding on stored produce, actual losses are much higher, as rodents contaminate the stored produce with urine, faeces, hair and pathogenic agents. As it is extremely difficult if not impossible to remove filth produced by rodents from the stored produce, infested batches often have to be declared unfit for human consumption.

There are around 50 diseases which can be transferred to man by rodents, including typhoid, paratyphoid, and scabies. In addition, rodents may be vectors of a large number of diseases affecting domestic animals. The problems and costs resulting from these diseases are not normally taken into account when assessing infestation by rodents.

As rodents prefer food rich in proteins and vitamins and feed mainly on the embryo, they cause particular damage to the nutritional value and germination ability of seeds.

- **Damage to material and equipment** (e.g. tarpaulins, bags, pallets, sprayers) and to the store itself (cables, doors).

These often lead to subsequent damage:

- Produce leaking out of damaged bags or storage containers
- Bags stacks collapsing due to damage to the lower layers
- Short circuits leading to sparks or fire from cables being chewed

- Silos and warehouses may subside or even collapse as a result of being undermined
- Drainage canals around a store may be damaged.

Signs of rodent infestation

When there are signs of rodent infestation, it is necessary to conduct a thorough investigation of the store, its immediate surrounding area and neighbouring land.

There are a large number of clear signs of rodent infestation:

Live animals
Rodents are mainly active at night. If animals are nonetheless seen during the daytime, this is a sign of an already advanced stage of infestation.

Droppings
The shape, size and appearance of droppings can provide information as to the species of rodent and the degree of infestation. The droppings of Norway rats are around 20 mm in length and are found along their runs. The droppings of Black rats are around 15 mm long and are shaped like a banana. Mouse droppings are between 3 and 8 mm in length and irregular in shape. Droppings are soft and shiny when fresh, becoming crumbly and matt black or grey in colour after 2 - 3 days.

Runs and tracks
Runs, such as those of Norway rats, are to be found along the foot of walls, fences or across rubble. They virtually never cross open areas of land, but always pass through overgrown territory, often being concealed by long grass.
Runs inside buildings can be recognized by the fact that they are free of dust. The animal's fur coming into contact with the wall leaves dark, greasy stains. Even Black rats, which do not have any fixed runs, can leave similar greasy stains at points which they pass regularly, e.g. when climbing over roof beams.

Footprints and tail marks
Rats and mice leave footprints and tail marks in the dust. If you suspect there might be rodent infestation, scatter some sort of powder (talcum powder, flour) on the door at several places in the store and later check for traces. The size of the back feet serves as an indication of the species of rodent:

- Back feet larger than 30 mm: Black rat, Norway rat, Bandicoot rat.
- Back feet smaller than 30 mm: House mouse, Multi-mammate rat, Pacific rat.

Tell-tale damage
Rats leave relatively large fragments of grain they have nibbled at (gnaw marks). They generally only eat the embryo of maize. Sharp and small leftovers are typical for mice. Rodent attack can further be detected by damaged sacks where grain is spilled and scattered. Small heaps of grain beneath bag stacks are a clear sign. These should be checked for using a torch on regular controls.
Attention should be paid to damaged doors, cables and other material.

Burrows and nests
Depending on their habits, rodents either build nests inside the store in corners as well as in the roof area or in burrows outside the store. Rat holes have a diameter of between 6 and 8 cm, whereas mice holes are around 2 cm in diameter. These holes can be found particularly in overgrown areas or close to the foundations of a store.

Urine
Urine traces are fluorescent in ultraviolet light. Where available, ultraviolet lamps can be used to look for traces of urine.

Preventive measures

The most essential factors for the occurrence of rodents are:
- sufficient supplies of food
- protected places in which to build burrows and nests
- hiding places
- access to produce

Good store management and preventive measures taken as part of an integrated control programme can help to deal with these factors.

Storage Hygiene and Technical Measures
- Keep the store absolutely clean! Remove any spilt grain immediately as it attracts rodents!
- Store bags in tidy stacks set up on pallets, ensuring that there is a space of I m all round the stack!
- Store any empty or old bags and fumigation sheets on pallets, and if possible in separate stores!
- Keep the store free of rubbish in order not to provide the animals with any places to hide or nest! Bum or bury it!
- Keep the area surrounding the store free of tall weeds so as not to give the animals any cover! They have an aversion to crossing open spaces.
- Keep the area in the vicinity of the store free of any stagnant water and ensure that rainwater is drained away, as it can be used as source of drinking water.

Keeping Rodents Out
The requirements of preventive rodent control must be taken into account whenever new stores are being built. Particular attention should be paid to doors, ventilation openings, brickwork and the junctions between the roof and the walls. Repair any damage to the store immediately! This applies especially to the doors.

For more information concerning rodents, visit the Rodent and Snail Management section of the Rice Knowledge Bank, located in the Integrated Pest Management Section (IPM).

(source: Gwinner et al, Manual on the Prevention of Post-harvest Grain losses, GTZ, Escborn, 1996)

Bird Control

Birds can be controlled by birdboys, birdnets or other scare mechanisms. For best effects, bird scaring devices need to be rotated.

1. Birdboys: If used, birdboys need to be present at critical times of 6-10am and 2pm-6pm.
2. Birdnets: For isolated areas of less than 0.25 ha, birdnets (at cost) can be used.
3. Additional suggestions - for crop establishment - direct seeded fields:
    - Cover seed with soil upon planting.
    - Increase seed rate.
    - Place bird scaring devices - e.g., tape, models of hawks, kites, models of snakes.
    - Employ bird boy.
    - Plant in season - avoid field being planted or harvested out of season, thus becoming focal points for attack.

Safe Applications

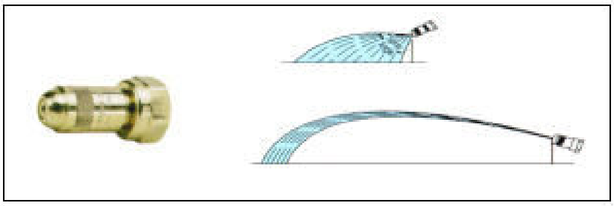
Principles of Application

The section on safe applications highlights a number of key principles involved in making a decision on how best to apply a product.

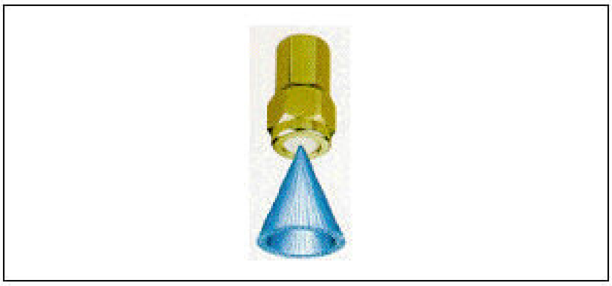
The first step in applying a product is to determine what is the target and what type of application is required. Systemic products can hit part of the target and be translocated to have their effects. Thus, larger droplets and lower operating pressures can be used. For contact products, good coverage is required. Thus, smaller droplets are required to ensure better coverage. The factors affecting the efficiency of applications are:

Operating pressure and droplet size

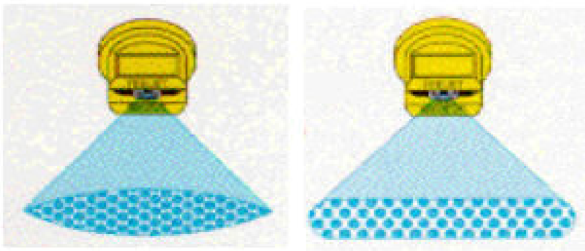
1. Nozzle type



Variable cone nozzle



Hollow cone nozzle


Even fan nozzle

2. Application conditions (See Wind effects on application)


Spray drifting in the wind

3. Type of equipment


Backpack sprayer

4. Operator skill

Spraying with safe equipment

Each of these are discussed below:

Pressure and droplet size

- Higher pressures reduce droplet size and can lead to increased drift.
- Smaller droplets have better coverage and therefore are good for contact pesticides such as fungicides and insecticides.
- Droplet size is measured in microns - 1 micron = 0.001 mm
- Droplets less than 100 micron (0.1 mm) are considered susceptible to drift.
- Backpack lever-operated sprayers operate at around 15 psi (1 bar)
- With mechanized systems, sprayers are usually run at around 30 psi (2 bar) although they can be run at 15 psi (the minimum pressure required to break up droplets).
- Pressure control valves are now available to help maintain a constant spray pressure and droplet size. This ensures more uniform pressure and thus more uniform application.
- Controlled droplet applicators (CDA) can apply in the range of 50-300 micrometers
- Pressure is not a good way to increase volume of output. To double output requires four times as much pressure

Application conditions - Best time to apply:

- Applications are best in the mid to late afternoon, although wind is often a problem.
- The next preferred time is early mornings.
- Note though that some products require sunlight for their action - check the label for specific instructions.

Nozzles

- Height: The nozzle(s) should be 0.3-0.5 m above the target.
-

Nozzle types:

- Cone nozzles produce finer droplets and are often used for insecticides and fungicides,
- Fan nozzles produce a coarser mist and are used for herbicide.
- A single cone nozzle can be used for more directed application at the base of the plant - double cones for more general applications.
- There are various types (e.g., fan or flat nozzles - some apply uniformly across the width of the nozzle spray (e.g., for single nozzle applications with backpack sprayers) and some taper off towards the edges (for multi-nozzle booms with overlap).

NOTE: Different companies use different codes

Example 1 - What does 8002 mean?
The first two numbers indicate the nozzle spray angle and the last two refer to the aperture. Therefore 8002 applies at 80o and would apply at half the volume of an 8004 nozzle.

Example 2 - What does110-LD-015 or F110/0.6/3 mean?
110 = nozzle angle; LD = low drift, · F = fan; 110= nozzle angle; 0.6 = flow rate (l/min) at 3 bars Pressure of application

- Typical average walking speed is just under 1 m/s

Changing spray volume
Spray volume can be changed by altering:

- Speed - change in volume is direct - double the speed halves the amount applied per area.
- Nozzle type - direct effect based on the size of the aperture
- Pressure - proportional effect. To double output requires four times as much pressure

Considerations in spray applications

- Training required - Applicators need to be aware of:
- Calibration - how much water applied per area and how much product is required and applied
- Toxicity - need to be aware of product toxicity and safe use practices - lower personal and environmental risk by using low toxicity products safely
- Use personal protective equipment (e.g., gloves, mask, overalls, goggles, etc.)

Equipment operation and maintenance
Application principles:

- Safety for the user and the environment
- Reduce drudgery
- Improve uniformity, timeliness and precision
- Reduce chemical loading: Lower chemical inputs
- Improve affordability: make equipment safe and affordable.
- Rotate product use to reduce the development of resistance in the target pest.

Equipment considerations

- Operator should ride and not walk to reduce drudgery
- Application should be behind or beside the operator

- Improve technical and economic application efficiency - use the right equipment for the job

Wind Effects on Application

Approx. air speed (m/s)	Description	Visible signs	Spraying
<0.3	Calm	Smoke rises vertically	Avoid spraying on warm sunny days
0.6-0.9	Light air	Direction shown by smoke drift	Avoid spraying on warm sunny days
0.9-1.81	Light breeze	Leaves rustle, wind felt on face	Ideal spraying
1.81-2.7	Gentle breeze	Leaves and twigs in constant motion	Avoid spraying herbicides
2.7-4.0	Moderate	Small branches moved, raises dust or loose paper	Spraying inadvisable

Calibration

Calibration is the output per unit area (e.g., l or kg/ha). It depends on:

- Speed of application
- Equipment output/unit time
- Width of application

You can calibrate by two methods:
Procedure 1 - The total output in a given area

- Measure a given area (e.g., 500 sq m)
- Measure the output from the sprayer or spreader to cover the area

  Example
  Test area = 200 sq m
  Output to cover area = 2 l
  Calibration = 2 l/200 sq m*10,000 sq m/ha = 100 l/ha

Procedure 2 - Combining output per unit time with the time required to cover an area

- Measure the operating speed (e.g., time to cover 100 m)
- Measure the output from the sprayer or spreader in a given time (e.g., 1 minute)
- Measure the width of application

  Example
  Speed = 120 s/100 m = 1.2 s/m
  Product output = 2 l/min
  Width of application = 4 m
  Calibration = 2 l/min*120 s/(100*4 sq m)* 1 min/60 s * 10,000 sq m/ha = 100 l/ha

Safety Considerations

Components of Risk

Pesticides are toxic compounds and as such we need to lower the risk for the user and the environment. The risk associated with agro-chemical applications can be summed up by the following equation:

Risk = toxicity x use

Risk is a combination of the toxicity of the product and the manner in which it is used. Thus risk can be lowered by using safer agrochemicals and by improving the application practices.

Agrochemicals in Perspective

Many products we take for granted are potentially harmful. For example, products such as gasoline, table salt, butter, margarine and toothpaste are all potentially harmful. Toothpaste, for example carries various warnings along the lines of:

"Warning - if swallowed seek medical advise"

Another example involves the raspberry. It has been said that if a chemical company invented raspberries, they would not be allowed to sell them because of their composition.

The important issue with such products is not to have us worry, but to point out that with judicious and safe use, such "common" products can be used safely. It seems logical to bring such a perspective to agrochemicals. After all, many household products are actually more toxic than many agrochemicals. We should therefore put agrochemicals in perspective and ensure that if farmers use them, then they are used only if needed and then only in a safe manner.

As seen above, the personal risk associated with chemical use has been defined by toxicology experts as a combination toxicity of the product x method of use. Thus, toothpaste although toxic when used correctly is safe. These are the principles that need to be applied if and when agrochemicals are used.

To put agrochemicals in perspective, I will discuss the pests, management options and then IRRI initiatives to improve safety.

Common Pests

Before talking of integrated pest management - often known as IPM - let's first consider what are the pests of rice and why. The main pests include:
Snails which can eat young plants and reduce plant stand - no plants - no yield.

Rats which can eat rice at all stages from planted seed to stored grain.

Insects - many different kinds - which can be important at different stages, either chewing, sucking or spreading diseases.

Weeds which can grow throughout the cropping season competing for light, water and nutrients.

Diseases which can be seed, soil or wind-borne and can affect crops throughout the life cycle.

Birds which can eat seed at planting and damage panicles during grain filling.

Why are Pests a Problem?

Primarily the above pests have the potential to cause significant yield and profit loss. It is the threat of this potential that often leads to farmers taking action. It's somewhat like a human inoculation program - the threat of the disease leads to wide-spread action.

What can the Farmers Do?

There are a range of options for control as shown in the table:

Pest	Management Options
Snails	Drain fields, place canalettes, hand pick, plant older seedlings, place trap materials, overplant, apply molluscicide or other products (e.g., rice hull)
Rats	Sanitation, habitat reduction, flame throw, overplant, bait, traps
Insects	Variety selection, timeliness, apply insecticides
Weeds	Crop management (tillage and water management, land leveling), hand weed, Apply herbicide
Diseases	Crop residue management, Variety selection, Apply fungicide
Birds	Scarecrows, over plant, synchronize plantings

For more detail, see materials under:

- **Insect management**
- **Disease management**
- **Weed management**
- **Snails, rats, and birds**
- **Integrated control measures for rice pests.**

Why do Farmers use Agrochemicals?

Why do we buy milk from a store and not milk our own cow? The answer is a combination of convenience, practicality, availability, and cost, etc.. A farmer uses similar logic in making management decisions. If there are so many options, why do farmers use agrochemicals. As mentioned, in producing a crop, farmers are balancing many factors including: labor requirements, cost, drudgery and timeliness of operation to ensure crop success to reduce risk and so improve their livelihoods. They are balancing what can be referred to as: Profit & pain - their returns (profit) relative to the pain of taking the action (possible drudgery) and/or not taking any action (risk).

For example, in weed management, labor requirements are in the order of: 120 hrs/ha for hand weeding, 50-70 hrs/ha for rotary weeding and 4 hrs/ha for backpack spraying. Some form of weed control is often required. However, as labor in some areas becomes scarcer or more costly, farmers therefore often turn to applying agrochemicals.

Integrated Pest Management (IPM)

So how do we balance the use of agrochemicals with need? As seen above there are a number of options for reducing pest problems. Also as we have seen in other papers, IPM is about using biological control, host plant resistance, and cultural practices, while minimizing or eliminating agro-chemical inputs. The basis of IPM is to put each factor in perspective to maximize benefit while lowering cost and protecting the environment and the user.

Such perspective requires knowledge and so needs education and time. There are various forms of personal, environmental and profit risk involved in pest management and the farmer needs to understand each factor. Typically, the farmer manages such risk by trying to maximize profit by reducing crop losses and costs and so they are making judgment calls on whether to act or not to act. It is at this point that extra knowledge may be required.
This is where we strike an important limitation in Asia - access to knowledge. For example, you can go to the shop to buy the input, but where can the farmer go to "buy" knowledge to make management decisions?

A major consideration with agro-chemical use involves personal and environmental safety. Considerable effort is focused on protecting the crop, but less effort is apparent on protecting the farmer? IPM obviously takes partial care of this by reducing the use of agrochemicals, but we see few activities - especially where farmers are applying agrochemicals - in the area of promotion of safe application options for farmers. It is in this area through it's own safety program in agro-chemical application that IRRI seeks to identify and at times develop safer application equipment and practices for farmers.

Safety Efforts at IRRI

IRRI has a history of being proactive in promoting safety and reducing agro-chemical use. Examples include:

1. Since establishment, IRRI has adopted standards consistent with various International (FAO, WHO) guidelines for health and application. These International standards have now been formally adopted (1999).
2. IRRI introduced a Trained Pesticide Applicator (TPA) program in 1987. Applications of pesticides can only be made by those trained and authorized to do so. IRRI showed considerable regional leadership in this scheme in that it was only in the same year that training for applicators became required in UK. The TPA program provides training to improve the uniformity of application, limit exposure and ensure safety for the operator and the environment. The program includes regular health monitoring.

3. IRRI vigorously pursues a program to have improved personal protective equipment. The TPA program ensures protective gear is worn, and such gear is upgraded as improved equipment becomes available.
4. IRRI also vigorously pursues a program to have improved spray application equipment. Application equipment is drawn from around the world to ensure the best available equipment is used at IRRI. This equipment then offers our visiting clients the opportunity to see improved equipment in action.
5. Agrochemicals differ tremendously in their potentially harmful effects. Recognizing this, agrochemicals defined by the World Health Organization as Category 1 have not been used since 1989 at IRRI. IRRI took this stand even though such products were still available on the market and regularly used by farmers.
6. In 1991, IRRI introduced a field monitoring scheme to assess insect, disease, weed and snail problems in fields.
7. IRRI endorsed IPM as the station standard in 1995. Since adoption, there has been a significant reduction in agrochemicals applied - a halving of the amount of insecticide active ingredient/ha applied.
8. In addition to its own search for improved practices, IRRI in 1997 - on an on-going basis - commissioned continual review by a UK application expert of its application practices and guidelines.
9. IRRI was a pioneer in raising concerns about agro-chemical use producing both a book and a video on the topic.

NOTE: IRRI does not develop agro-chemical products. It does have projects though looking at non-chemical forms of control - e.g., bio-control.

Safety Considerations in Applying Agrochemicals

In part from comments from Chris Meeks - Pesticide application specialist - observations based on pesticide safety guidelines based on the UK.

The application objectives should include:

- Safety for the user and the environment
- Drudgery reduction
- Uniformity, timeliness and precision of application
- Lower chemical chemical loading by reducing inputs
- Affordability: Application options should be safe and affordable

Equipment considerations

- The operators if possible should ride not walk to reduce drudgery
- Applications should be behind or downwind of the operator to reduce contamination - most contamination occurs from the applicator walking through the sprayed crop.
- Technical and economic application efficiency - use the right equipment for the job

Other considerations

- The time of mixing is considered the most critical (the operator is at greatest risk when mixing and pouring the concentrate). A face shield is essential. A cartridge mask is not strictly necessary at this point as there are few driftable droplets produced (See latter comments on smell).
- By the time application is made in the field, the product is normally diluted in a ratio of 50 to 200:1.

- Due to the large percentage of inert material in most pesticide formulations, the percentage of active ingredient per l of spray mixture would be less than the above figure as the active ingredient is only a part of the product (i.e., Round-up is at a strength of 360 g/l or 36%).
- When mixing and pouring, it is imperative that no concentrate is either ingested through the mouth, nose or eyes or absorbed through the skin around the face. The standard protective face shield ensures, under normal operating conditions, that the operator is not exposed to this hazard.
- During a non-routine event such as an accidental spillage or splashing, the face shield will ensure the operator remains uncontaminated.
- During field application, the purpose of protection is to ensure that dilute spray droplets that drift onto the operator do not cause harm. This can be achieved by ensuring the following:

  Following manufacturers recommendations for mixing rates and volumes of application.
    - The use of pressure regulation below a delivery pressure of 2 bar to ensure that the production of driftable droplets below 100 microns is kept to a minimum. (We are using 1 bar pressure regulators at present in many sprayer applications.)
    - In the event of driftable droplets reaching the operator, it is advisable for the operator to wear (a) an approved mask to minimize inhalation or ingestion and (b) glasses or goggles. (A face shield is not normally used as the mask is in the way.)

- The smell often associated with pesticide application operations is usually attributed to the solvent carrier in the formulation. Pesticides are similar to paint in the fact that part of the carrier may be constituted of inorganic chemical solvent. Due to the volatile nature of these solvents (as is their purpose) they may be detected a great distance from the source. However, these molecules are now disassociated from the active ingredient.

Post Production

Principles of Post Production

The section on post-production highlights the importance of managing grain moisture at the various stages of post-production management. It provides general guidelines for all post-production operations including harvest, grain cleaning and drying, storage, and milling as well as a section on rice by-product uses.

Post-production includes all operations starting from harvesting: cutting, stacking, hauling, threshing, cleaning, drying, storage, milling, and grading. Rice quality The key to post-production is correct timing of operations to manage grain moisture content (**MC**). Target MC for key post-production operations are shown in the Table:

Operation	Desired Moisture Content (%)	Primary Cause of Losses
Harvesting**	20-25 (California: Short and medium grain (23%) and Long grain (18%) - these MCs are a little lower than for the Tropics.)	Shattering if grain is too dry
Threshing	20-25 for mechanical threshing (varies slightly with variety: e.g., California: Short and medium grain (23%) and Long grain (18%) - these MCs are a little lower than for the Tropics.) <20 % for hand threshing	Incomplete threshing, grain damage and cracking/breakage
Drying	Final moisture content is 14% or lower	Spoilage, fungal damage, discoloration, smell
Storing	<14% for grain storage <13% for seed storage <9% for long term seed preservation	Fungal, insect & rat damage, smell
Milling	14%	Grain cracking and breakage Overmilling - (i.,e., remove more kernel than needed)

* the Moisture contents stated in the table are for tropical, humid climates typical for most rice-growing countries in Asia.

** For fully mechanized harvesting, optimal moisture contents are often a trade-off between grain quality and costs for mechanical drying . Because wetter rice is more expensive to dry, growers frequently harvest rice at a moisture content lower than what is best for quality. For most varieties, the trade-off MC is 22% +/- 1%. The exception are long grain varieties which are harvested at lower MC (20% or less) as they contain less moisture than medium or short grains.

Calculating moisture content
Moisture content can be on a wet (MC wet) or dry (MC dry) basis:

- MC wet = Weight of moisture in wet grain * 100/(weight of wet grain)
- MC dry = Weight of moisture in wet grain * 100/(weight of dry grain)

Moisture Content

Calculating Moisture Content

Moisture Content (MC) of grain (i.e., the amount of moisture in the grain) is usually determined on wet basis:

- MC wet = Weight of moisture in wet grain * 100/(weight of wet grain), or:
- MC wet = (Weight of wet grain - Weight of dry grain)*100/(weight of wet grain)

During drying, paddy grain loses weight due to the loss of moisture:

- Final weight of grain = Initial weight * (100- MC initial %)/(100-MC final %)

Example: 1000 kg of paddy is harvested at 25% MC, and dried down to 14% MC
final weight of grain = 1000* (100-25)/(100-14) = 872 kg of paddy at 14 % MC

Measuring Moisture Content

Moisture content of grain can be measured by using a drying oven, or by using a commercial moisture meter

Measuring MC with a drying oven:
1. Pre-heat the oven to 130°C (Note: Temperatures above 40°C will kill grain samples)
2. Weigh three paddy samples of 10 grams each and place them inside the oven
3. Remove the samples after approximately 16 hours, and obtain the final weight of each sample
4. Compute the MC for each sample :
5. MC = (10 - Final weight of dried sample in grams)*100/(10)
6. Compute the average MC of three samples

Measuring MC by using a commercial moisture meter:
There are many different types of grain moisture meters (click here to see photo). Make sure your meter is suitable for paddy grain. Consult the manual to find out the correct procedure for measurement.

The following is the procedure for the Kett Rice Tester.
NOTE: IRRI does not endorse any particular brand or type of moisture meter.

1. Turn on the moisture meter and make sure that button indicating "paddy" is on.
2. Fill the tray of the moisture tester with paddy to the required level.
3. Turn the knob until the moisture reading is displayed.
4. Take measurements of 3 to 5 samples and compute the average MC

NOTE: Most moisture meters have to be calibrated using MC calculated using an oven.

Factors Affecting Grain Quality

Variety

Different varieties have different physical and chemical characteristics that affect grain quality and yields. The dimension, shape, weight, volume and density of grains determine the physical characteristics of rice and in turn influence head rice yield. Varieties that:

- Have short and medium type grains, which are more rounded, thicker and harder than long grains produce higher head yield.
- Are earlier maturing tend to produce less head rice than late maturing varieties.
- Fill uniformity have higher grain density and less chalkiness
- Flower unevenly also ripen unevenly. Non synchronous varieties can have a variation of up to 10% in moisture content and take 5 days longer for the grain to mature at the bottom of the panicle, when compared to the grain in the top of the panicle.

Crop Management

Crop Management

The management of the crop will influence the time and uniformity of crop maturity. Basic requirements of good crop management include good:

- Crop establishment
- Water management, and
- Nutrient management

The following table summarizes the general effects of crop management on rice quality:

Production factor	Possible effect on quality	Recommendation
Land preparation & Leveling	If a field is not level, then crops, especially under direct seeded conditions, will generally emerge differentially. Delaying maturity can result in a wider spread of grain moisture at harvest and damaged	Prepare fields as level as possible

	grain if the crop is mechanically threshed. Uniform water depth throughout the season will contribute to uniform ripening across the field and consequently more consistent moisture content in the grain between locations. Cut areas may mature sooner than fill areas of a field. Large differences in grain moisture content in rice contribute to fissuring and accelerate spoilage.	
Crop establishment and replanting	Replanting will delay maturity resulting in a wider range of moisture contents at harvest (See above).	Limit replanting by ensuring good land preparation & leveling
Variety	Genetics plays a dominant role in grain quality - especially for length, shape, chalkiness and amylose content.	
Seeding date	Seeding date can affect conditions during maturation. High temperatures after flowering can lower the amylose content, increase chalkiness and increase gelatinization temperature. Grain length is little affected by environment.	Avoid planting to have the rice maturing during periods of high temperature.
Seeding rate	Higher seeding rates will lead to higher plant population, more competition for limited resources, and possibly more lodging and smaller grain size. Lower seeding rates will result in increased tillering with possibly more variation in maturing within the panicle, and higher weed populations.	Select right seeding rate

Nutrient management	Uneven crop nutrition can lead to variation in tillering and tiller maturity across a field resulting in a range of grain moisture content at harvest. Nutrition can affect head rice and amylose content. Delayed nutrition may lead to delayed growth and crop maturing, which increases the probability that the crop is affected by adverse weather during harvesting season (typhoon, rain, etc.)	Ensure uniformity of nutrition across the field. Timely nutrition.
Water management	Kernel weight is very stable, although variation up to 10% can be found. A 10% volume difference equates to around 3% variation in grain radius. Under stress, rice tends to abort excess grains and fill fewer grains instead. Too early drainage prior to harvest may lead to incomplete grain filling and more misshapen kernels. Too late drainage prior to harvest may lead to inability to harvest rice at right moisture content (due to field inaccessibility).	Keep fields level. Drain field at the right time.
Pest control **Insects** **Weeds** **Diseases** **Rats** **Snails** **Birds**	Insects such as stink and rice bugs that attack the grain during soft or hard dough stages can result in deformed or spotty grains. The spotty grains come from infection by bacteria transmitted during feeding. Late applications of pesticides may result in	Good land leveling, tillage, water management, and timely weed control Timely harvesting, threshing, and drying to neutralize fungi brought in from the field.

	unacceptable pesticide residues in the grainHeavy weed infestations can reduce grain quality by out-competing the rice for resources (nutrients, sunlight), or by contaminating the rice with weed seeds with high moisture content. The latter can lead to a differential transfer of moisture within the grain mass that promotes fissuring. Stemborers cause whiteheads and thus add unfilled grain (i.e., material other then grain) to the harvested material, but don't have much other effects. Rice crop in the field is contaminated with numerous fungi. Under high moisture and high temperature conditions some fungi (e.g. smut) may develop before harvest. Most fungi in the field require a grain moisture content of more than 22% to develop. After the rice is harvested and dried down, these fungi die and a different group of fungi (storage fungi) will develop. A high incidence of smutted kernels will drastically reduce grain quality.	
Grain moisture content at harvest	Grain formation starts from the tip of the spikelets from the top of the panicle. Thus, any given panicle will have grain having a range of	Dry grain and keep dry.

	moisture contents. Re-adsorption of moisture after grain MC drops to 15% or less will result in fissuring.	

Crop Establishment

Establishing the correct number of plants is essential to maximize water and nutrient use. A target population that results in 4-500 panicles per m-2 is desirable. This means establishing at least 70-100 seedling m-2 when transplanting, or broadcasting 80-120 kg seed ha-1 when direct seeding.
Low populations may result in:

- increased tillering, which creates more variation in panicle maturity,
- increased weed populations, and
- reduces the yield potential of the variety.

High plant populations may reduce yield and quality by:

- competing for water and nutrients,
- mutual shading,
- lodging and
- reduced grain size.

Water Management

To be able to manage water, the fields must be level and the bunds or levees well maintained. Uniform water depth across the field will contribute to more uniform crop, higher grain yields, uniform maturity and thus more consistent moisture content in the grain sample. Reducing the variation in moisture content at harvested reduces grain fissuring (cracking) and also reduces the chance of spoilage through yellowing and of odors.

Good water management helps reduce weed competition, which not only increases yields but also improves grain quality by reducing dockage levels and reducing moisture differentials between weed seeds and grain. Wet spots in the grain due to uneven drying or weed seeds can lead to off odors and discoloration of the grain.

Nutrient Management

Supplying the correct level and type of nutrients for the variety and growing conditions is essential. The prudent application of nitrogen is essential to get an even maturing crop with full grain size and high protein levels. Excessive and uneven application of N can stimulate late tiller production, which results in heads on the main culm ripening a number of days faster than the tillers. This results in more immature and green heads in the sample as well as higher moisture content that increasing the chance of fissuring and spoilage. Conversely insufficient nitrogen can lead to reduced grain size and protein content.

Harvesting

Introduction to Harvesting

Harvesting can be done manually, or mechanically with the use of machines. Below are a number of guidelines that will ensure that grain quality is preserved during harvest operations, and that losses are kept to a minimum.

- **Timeliness: Harvest and thresh at the right moisture content**
- **Avoid rewetting of harvested kernels**
- **Avoid delays in threshing**
- **Use proper thresher machine settings**
- **Clean grain thoroughly after threshing**

Timeliness: When to Harvest

Harvest and thresh at the right moisture content. Grain moisture content at harvest is crucial in preserving grain quality and reducing grain loss. **Crops should be cut at 20-25% moisture content or when 80-85% of the grains are straw colored and the grains in the lower part of the panicle are in the hard dough stage** - in the tropics, this is typically about 30 days after flowering. Correct timing of harvesting, reduces mechanical damage to the grain, as well as being a tradeoff between grain loss, optimum head rice and germination potential. Below 20% or above 25% grain can be damaged (cracked) during mechanical threshing or grain is lost due to shattering.

Grains should be firm but not brittle when squeezed between the teeth. If the crop is too dry, fissures will form in dry kernels and when these are rewetted, they break during milling. If the crop is harvested too early, there will be many immature grains that will reduce milling yield and head rice recovery. The immature rice kernels are very slender and chalky and this results in excessive amount of bran and broken grains.

Correct timing of harvesting is crucial in preventing quality deterioration. Harvest the crop when 85 % of the kernels are straw-colored.

Avoid Rewetting

Avoid rewetting of harvested kernels: When kernels are rewetted they can form fissures that break during threshing and milling - lowering head rice recovery. To avoid rewetting and reduce grain breakage, thresh and dry the grain as soon as possible after cutting.

Fissures in rice as seen through a red light filter. Fissured grain will break during milling and therefore fissures reduce the market value of rice considerably. Common causes of fissuring are rapid moisture loss of the grain during drying, and exposure of dry grain to moist air. Harvest and dry your paddy in time to prevent fissure formation. Do not mix wet grain with dry grain.

Avoid Delays in Threshing

Immediate threshing reduces the exposure of crop to insects, birds and rodents, disease, and molds. Crop that is piled over a period of time generates heat that serves as an ideal medium for growth of molds, disease and pests. Discoloration increases dramatically when the crop is stacked for 3-4 days. Germination and spoilage can also occur. While piling can lead to problems, field drying prior to threshing can lead to a rapid reduction in moisture content to below 20% (i.e. too dry for mechanical harvest), and can lead to high shattering losses.

Postponing threshing by piling the harvested crop along the field for more than day will result in heat buildup in the grain. This will result in grain discoloration and lower quality of milled rice. If you rely on a contractor for threshing, avoid delays in threshing by choosing a harvesting date depending on the availability of the contractor.

Proper Machine Settings

The drum tip speed of the threshing drum should be about 12-16 m/sec, equivalent to around 600 rpm for most threshers (with a 20 - 25 cm radius drum). Higher speeds result in higher grain damage. Lower speeds increase the amount of non-threshed grain and result in grain loss. **Clearance between threshing teeth and the concave** should be about 25 mm: smaller clearance increases grain damage.

Proper Machine Settings for Combine Harvesting

Use proper machine setting for combine harvesting. Combines require settings unique to the crop, variety and maturity. Most harvester manuals give initial settings for the crop, but the operators should adjust these based on conditions in a given field and the threshing characteristics of the particular variety. Medium or short-grain varieties are more difficult to thresh than long grain varieties. More difficult to thresh varieties require higher cylinder drum speed, smaller concave clearance, and lower blower fan speed.

The picture shows heavily damaged paddy indicated by partially and fully husked grain, and grain breakage. Mechanical damage to paddy grain can be a problem in harvesters, threshing machines or grain dryers when they are not adjusted or operated properly.

Clean Grain

Clean grain thoroughly after threshing: Remove all materials other than grain, including straw, chaff, immature grains, and unfilled grains. Foreign materials will affect grain quality during storage and milling, and reduce milling recovery. If the crop is machine threshed, adjusting the blower to the correct speed (~800 rpm) will provide good initial cleaning. For more information on grain cleaning see the next section

Grain Cleaning

Introduction to Grain Cleaning

Grain cleaning after harvest is important as it removes unwanted materials from the grain. Clean grain has a higher value than grain that is contaminated with straws, chaff, weed seeds, soil, rubbish, and other non-grain materials. Grain cleaning will improve the storability of grain, reduce dockage (i.e., price penalties) at the time of milling, and improve milling output and quality. Seed cleaning will reduce damage by disease, and improve yields (Link to **clean seed**). Following are some general guidelines for cleaning grain and seed.

Harvested paddy grain typically contains quantities of straw, chaff, unfilled grains, immature grains and other impurities. Clean grain is easier to dry, has better storability, and will produce better quality of milled rice. Clean the grain prior to storage and milling to attain high milled rice quality.

Winnowing

Lighter materials such as unfilled grains, chaff, weed seeds, and straw can be removed from the grain by using a blower, air fan, or by wind. Recover only the heavier seeds.

The simple traditional cleaning method is winnowing, which uses wind or a fan to remove the light elements from the grain. Mechanical winnowers that incorporate a fan and several superimposed reciprocating sieves or screens are now used in many countries. These can be manually powered or motorized and have capacities from 100 kg to 2-3 tons per hour. Where combine harvesters are used, there is a trend towards using large capacity centralized seed cleaners. These are normally equipped with a series of vibrating sieves and are capable of 10-30 tons per hour.

Winnowing is an important technique for cleaning grain at the farm level. If there is not enough wind, simple electric air fans can be used to separate lighter materials from the grain.

Screening/Sifting

Smaller materials such as weed seeds, soil particles and stones can be removed by sieving the grain through a smaller sized screen (a screen of 1.4 mm or less sieve opening is typically used).

Sifting can be done either by mechanical grain cleaners, or by hand with simple sieves as shown in the picture.

Seed Cleaning

Malformed, discolored, germinated, broken or moldy grains in seed lots can severely impact seed quality, viability and vigor. Visually inspect the seed prior to storage and consider removing these grains from the seed lot.

Seed Grading

For commercial seed processing, seed grains should have uniform size and weight. A variety of commercial equipment can be used to achieve uniformity in seed size and shape. These include gravity tables, rotary screens, indented cylinders, and length graders.

Photos of Seed Graders:

Seed Purity

Maintain seed purity by preventing mixing with other varieties, and contamination with other species.

Grain Drying

Introduction to Grain Drying

Drying will reduce grain moisture content down to a safe level for storage. Drying is therefore the most critical operation after harvesting. Paddy should be dried to 14% MC as soon as possible after threshing. (See **grain storage** for an indication of grain moisture contents and safe storage periods.) Drying provides preliminary control against insect infestation, and reduces losses from natural respiration. Proper drying procedures ensure paddy with good milling quality (i.e., high head rice, and high milling recovery).

Drying involves two stages - drying of "surface" moisture which brings grain moisture content down to around 18% MC and then drying to remove "internal" moisture. The following are general guidelines for drying of paddy.

Effects of Delayed Drying

Do not delay drying of wet paddy. Delays in drying of wet paddy cause quality deterioration and physical loss with discoloration occurring increasing dramatically within 2-3 days after threshing. Paddy with high moisture content (>20% MC) must be dried as soon as possible down to 18% ("skin dry") then to 14% MC to preserve milling, cooking, smell, and eating qualities.

A general yellowing of the rice grain is a result of heat buildup in the paddy grain before drying. Discolored grain drastically reduces the market value of rice. Although discoloration is a complex biochemical process, it can be easily avoided by timely drying of paddy after harvest.

Sun Drying

The target for drying grain for storage and milling is 14% MC. If not done properly, sun drying can result in over-drying or paddy with variable MC. The guidelines for proper sun drying are:

- Turn or stir the grain at least once per hour to achieve uniform MC - variation in MC within the grain causes rewetting and subsequent grain cracking of drier grain;
- Keep the thickness of the grain bed between 5 and 10 cm;
- On hot days, the grain temperature can rise above 50-60ºC, thus cover the grain during mid-day to prevent over-heating;

- Cover the grain immediately if it starts raining. Rewetting of grain causes fissured grains and high grain breakage during milling
- Prevent contamination of grain with other materials, and keep animals off the grain
- Sun drying is presently the most common practices of drying in Asia. Typically it produces poor quality grain, but is very economical.

Sundrying is still the most common grain drying method used in Asia. Although the energy from the sun is for free, it is not an automatic process. Frequent stirring and turning of the grain (as shown) will reduce overheating and overdrying of grain, and improve uniformity of drying.

Machine Drying

The target for drying grain for storage and milling is 14% MC. For production of premium rice quality or quality seed, artificial drying with heated air dryers ("machine drying") is recommended. Machine drying will lead to more uniform drying of grain and higher milling yield and head rice recovery.

- The most common smaller dryers have a capacity of 1-3 tons per day with drying times of 6-12 hours. For drying of paddy in tropical areas an air temperature of 40-45 ^{o}C is normally used with a heater capable of raising the air temperature 10-15^{o} C. An air velocity 0.15-0.25m/s is required and typical power requirements are 1.5-2.5 kW /ton of paddy. The efficiency of these dryers is also improved by stirring the grain.

- Before loading the dryer, clean the grain by removing fines and green, immature grains. Fines reduce the air flow through rice, causing increased drying time and can cause wet spots.

- In the dryer, do not mix dry rice with wet rice. The drying air gains moisture as it passes through the dryer and may cause the dry rice to fissure.

Medium-sized grain dryers such as this recirculating batch dryer are now a common sight throughout Asia. In general, mechanically dried grain will produce better quality of rice. Grain recirculation allows for uniformly dried grain, and automatic drying air temperature control will reduce overheating or overdrying.

Drying for Seed Production

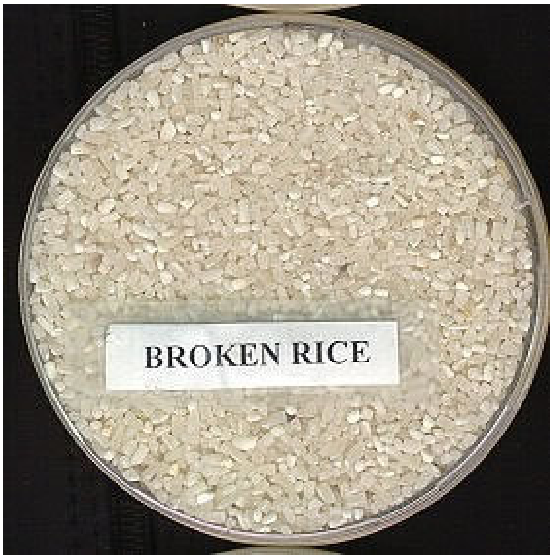
The temperature of the drying air should not exceed 43ºC. Drying air temperature affects seed viability. Some literature suggests you should use lower temperatures during first stage of drying of seed (if grain is very wet), so 40ºC is often seen as optimum. Exposing paddy to 60ºC for one hour can reduce seed germination rate from 95% to 30%. Two hours at 60ºC will reduce germination rate to 5%.

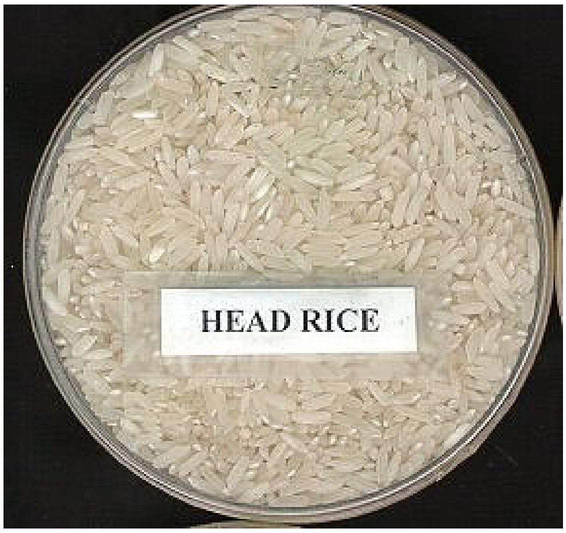
Dry seed below 13%. For successful storage of seed in sealed bags, pots, or containers, paddy should be dried down to 10-12% MC to provide long term seed viability and minimize insect damage. Seed can be safely stored in sealed containers. The lower the MC of seed at the beginning of storage, the longer the seed remains viable. (See **grain storage**).

Drying for Grain Production

Avoid over-drying (< 14% MC). If grain MC is lower than its **Equilibrium Moisture Content**, grain will reabsorb moisture from the atmosphere and crack. This results in lower head rice recovery and reduced milling recovery.

For very wet paddy, consider pre-drying with ambient air. Aeration reduces drying costs and maintains the eating quality of rice. High temperature drying of high moisture paddy causes deterioration of taste and decreases in germination. In general, aeration is possible if the Relative Humidity of the air is lower than 70%. See **Equilibrium Moisture Content**.





Broken rice (left) has about half the market value of Head rice (right). Proper drying procedures can minimize breakage in rice. Avoid overdrying (drying below 14% MC) and rewetting of dry rice to maximize head rice recovery.

Drying Rates and Temperatures

- The drying rate is dependent on type of dryer, air flow rate, etc. If the grain is suspended in air or somehow in motion (as in the recirculating dryer), it can be higher than fixed-bed dryers. For most batch dryers, drying rates are in the 0.75 to 1 % moisture decline per hour, on average for the entire drying process. Typical drying rates are around 1% moisture/hour at 65ºC and 0.5-0.75 % moisture per hour at 43ºC. The higher temperature can be used to dry grain down to 18 % MC (to remove "surface moisture") and then the lower temperature can be used to remove internal moisture from within the grain. In general drying rates for first stage are higher than second stage because during first stage moisture is readily removed as it sits in the "skin". Second stage drying involves removal of "internal" moisture.

- For seed, drying air temperature should never exceed 43ºC, regardless of the MC to avoid overheating of the grain which kills the germ.

- Using two stage drying means that you need to be able to carefully estimate MC during the drying process. If you can't or the MC is variable, it is better to stay with 43ºC. It is also recommended to include a tempering period before changing from higher to lower temperature drying.

- Do not leave wet rice in the dryer for extended periods. Undried rice may begin to heat, which causes the kernel to turn yellow.

Grain Storage

Conditions for Safe Storage

Safe storage of paddy grain for longer periods is possible if three conditions are met:
1. grain is dried down to 14% MC or less;
2. grain is protected from insects and rodents;
3. grain is protected from rewetting by rain or the surrounding air;

The longer the grain needs to be stored, the lower the required grain MC. Seed stored at MC's higher than 14 % will experience growth of molds and rapid loss of viability. The following table shows the MC required for different storage periods.

Storage period	Required MC for safe storage	Potential problems
2 to 3 weeks	14 - 18%	Molds, discoloration, respiration loss
8 to 12 months	13% or less	Insect damage
more than 1 year	9% or less	Loss of viability

Grain Storage

The key to good storage is hygiene and grain moisture contents. The target moisture for storage is less than 14%. The following table shows the storage possibilities and problems associated with different grain moisture contents.

Grain moisture content (%)	Safe storage	Possible problems
>40		Germination
18	2 weeks	
12-14	1 year	
>8		Insect damage
8-10	> 1 year	

Calculating moisture content
Moisture content can be on a wet (MC wet) or dry (MC dry) basis:
- MC wet = Weight of moisture in wet grain * 100/(weight of wet grain)
- MC dry = Weight of moisture in wet grain * 100/(weight of dry grain)

Gain moisture depends upon the temperature and the relative humidity of the air. The following table shows this relationship. Shaded cells show desirable environmental conditions for storage:

	Temperature (celcius)						
RH (%)	**22**	**24**	**28**	**32**	**36**	**40**	**44**
50	11.2	10.9	10.7	10.5	10.2	10.0	9.9
55	11.7	11.5	11.2	11.0	10.8	10.6	10.4
60	12.3	12.0	11.8	11.6	11.4	11.2	11.0
65	12.7	12.6	12.4	12.2	12.0	11.8	11.6
70	13.5	13.3	13.1	12.8	12.6	12.5	12.3
75	14.3	14.0	13.8	13.6	13.4	13.2	13.0
77	14.6	14.3	14.1	13.9	13.7	13.5	13.4
79	14.9	14.7	14.5	14.3	14.1	13.9	13.7
81	15.3	15.1	14.9	14.6	14.5	14.3	14.1
83	15.7	15.7	15.3	15.1	14.9	14.7	14.5
85	16.1	15.9	15.7	15.5	15.3	15.1	15.0
87	16.6	16.4	16.2	16.0	15.8	15.6	15.5
89	17.2	17.0	16.8	16.6	16.4	16.2	16.1
91	17.9	17.7	17.5	17.3	17.1	16.9	16.7

Hygiene for storage

- Keep storage areas clean
- When storage rooms are emptied, clean and before using again, consider spraying walls and crevices, including the wooden pallets, with the recommended insecticide to disinfest insect breeding places.
- Place sticky traps in the drying and storage areas for rats. (Keep a cat)
- Storage rooms should be physically rodent and bird proof, if possible.
- If necessary, treat storage sacks with insecticide to prevent insect infestation. This however is a dangerous practice if there is a chance that the seeds will be milled for consumption, and therefore is not recommended.
- Inspect the stored seeds once a week for signs of insect infestation. Should there be infestation, under the direction of a trained pest control technician, the storage room or the seed stock may be enclosed hermetically with tarpaulin and fumigants. Phostoxin is used by the grain milling industry. This will kill all insects, larvae, and rodents in the enclosure.
- For long term seed storage, store the seeds in bags in storerooms with controlled temperature and relative humidity. The recommended storage environment for rice seeds are <20C and 40%RH. In this conditions both fungi and insects will be inhibited.

Equilibrium Moisture Content of Paddy

In storage, the moisture content of rice depends on the temperature and the relative humidity of the air surrounding the grain. The final grain moisture content resulting from storage is called the Equilibrium Moisture Content (EMC). The following table shows the EMC of paddy under different storage conditions. **The underlined & colored areas** represent the desirable environmental conditions for storage of paddy in the tropics.

	Temperature (celcius)						
RH (%)	**22°**	**24°**	**28°**	**32°**	**36°**	**40°**	**44°**
50	11.2	10.9	10.7	10.5	10.2	10.0	9.9
55	11.7	11.5	11.2	11.0	10.8	10.6	10.4
60	12.3	12.0	11.8	11.6	11.4	11.2	11.0
65	12.7	12.6	12.4	12.2	12.0	11.8	11.6
70	13.5	13.3	13.1	12.8	12.6	12.5	12.3
75	14.3	14.0	13.8	13.6	13.4	13.2	13.0
77	14.6	14.3	14.1	13.9	13.7	13.5	13.4
79	14.9	14.7	14.5	14.3	14.1	13.9	13.7
81	15.3	15.1	14.9	14.6	14.5	14.3	14.1
83	15.7	15.7	15.3	15.1	14.9	14.7	14.5
85	16.1	15.9	15.7	15.5	15.3	15.1	15.0
87	16.6	16.4	16.2	16.0	15.8	15.6	15.5
89	17.2	17.0	16.8	16.6	16.4	16.2	16.1
91	17.9	17.7	17.5	17.3	17.1	16.9	16.7

Example: at 81% Relative Humidity and 32°C, paddy will attain 14.6 % Moisture Content.

Estimating Relative Humidity

For a crude but simple method to estimate Relative Humidity:

1. Measure the ambient air temperature with a mercury thermometer (Celcius)
2. Wrap the tip of the thermometer in a piece of cloth that is soaked in water
3. Measure the air temperature with the wetly wrapped thermometer while holding it in the wake of the wind or airfan.
4. The difference between the first ("dry") and second ("wet") temperature is a measure of the Relative Humidity:
    - 0 - 1°C difference: Relative Humidity is more than 90%
    - 2 - 3°C difference: Relative Humidity is between 80 and 90%
    - 4°C or more: Relative Humidity is 70% or lower

Hygiene in Storage

Hygiene in the grain store or storage depot is important in securing grain and seed quality over time. Following are some guidelines for hygiene in the grain store:

- Keep storage areas clean;
- Clean storage rooms after they are emptied, and consider spraying walls, crevices, and wooden pallets against insects before using them again
- Place rat traps in drying and storage areas, and keep a cat to deter or control rats and mice;
- Inspect storage room regularly to keep it rat and bird proof
- Inspect the stored seeds once a week for signs of insect infestation. Only if necessary and under the direction of a trained pest control technician, the storage room or the seed stock may be enclosed hermetically with tarpaulin and treated with fumigants

Pests in Grain Storage

Insects in stored rice can be classified into **four** groups according to their feeding habits namely internal feeders, external feeders and scavengers.

1. Internal Feeders - These are insects whose larvae feed entirely within the kernels of the grain. These includes rice weevil, angoumois grain moth and lesser grain borer.

- **Rice Weevil** *(Sitophilos oryzae (Linnaeus))*
- **Angoumois Grain Moth** *(Sitatroga cerealella (Olivier))*
- **Lesser Grain Borer** *(Rhyzopertha dominica (Fabricus))*

2. External Feeders - External feeders are insects that feed from the outside of the grain even though they may chew through the outer coat and devour the inside.

- **Cigarette or Tobacco Beetle** *(Lasioderma serricorne (Fabricius))*: Feeds on books, flax tow, cottonseed meal, rice, ginger, pepper, dried fish, crude drugs, seeds, pyrethrum powder, and dried plants.
- **Flat Grain Beetle** *(Cryptolestes pusillus (Schonherr))*: The female places her eggs loosely in the grain mass. The larvae and adults are able to penetrate the seed coat of the undamaged grain.

3. Scavengers - Scavengers feed on the grain only after the seed coat has been broken either mechanically or by some other insect.

- **Saw-toothed Grain Beetle** *(Oryzaephilus surinamensis (Linnaeus))*

4. Rodents in Storage

(source: Gwinner et al, Manual on the Prevention of Post-harvest Grain losses, GTZ, Escborn, 1996)

Storage Options

Besides temperature and relative humidity, the type of bag or container used is crucial for successful storage:

- **Traditional storage**: Typically grain is traditionally stored in 40-50 kg sacks made of jute or woven plastic. The grain MC in these bags will fluctuate as moisture in the air can freely transfer through the bag. A combination of high temperature and high relative humidity will lead to insect infestation in these bags, even if the grain was properly dried before storage. Bags are usually stacked under a roof or in a shed and will likely need periodic fumigation to control insects. Some farmers use granaries, which are made from timber or mud/cement or large woven baskets and these also suffer from insect and rodent damage.

Farmers often store seed and grain in claypots or woven plastic bags that are also used for fertilizer. Grain stored under these conditions is often exposed to moisture fluctuation, insects and rodents. Alternatives are available to improve storage conditions and reduce grain or seed quality deterioration.

- **Sealed storage**: For longer term storage of grain and seed, sealed or hermetic storage is an alternative. In such storage, carbon dioxide builds up and oxygen is reduced. The seed remains viable but insects can not survive. Thus, ensuring complete sealing is important. If grain is dried to 14% and stored in a sealed storage it reduces the risk of insect and rodent damage and the grain should not absorb moisture from the atmosphere or be damaged by rain. For storage up to one year, grain needs to be dried down to 13% MC or to 9% MC for storage longer than 1 year.

Recycled oil drums and PVC containers can be used as low-cost sealed storage devices for paddy seed and grain. Plastic containers like the ones shown can be commonly found throughout Asia and can hold from 25kg up to 250 kg of grain. Care should be taken to dry the grain to 13% MC before sealing, and to seal off the covers carefully to create a sealed environment inside the container.

Sealed storage containers come in all shapes and sizes. They may range from a small plastic container to a sealed 200-liter drum to the more complex and costly sealed plastic commercial storage units. Most large commercial steel and concrete silos being used in western countries can be sealed for fumigation.

Hermetic storage of grain has recently proved successful in keeping paddy seed viable for periods longer than 12 months. In the hermetically sealed storage environment, insects create a oxygen-deficient atmosphere that reduces insect infestation drastically and to an acceptable level. Hermetic storage is a good option for storage of grain and seed in particular where cold storage is not available or too expensive.

- For storage of **small seed lots**, a variety of plastic bags or packages can be used. Different types of plastic have different resistance against transmission of water vapor. Glass jars, hard pvc, or bags containing aluminum liners will provide best protection against moisture re-entry. Polypropylene or polyethylene bags are the next best choice. Use of paper bags or flexible pvc bags for long term storage of seed is discouraged.
- **Importance of temperature**: No bags or container can protect seed from the detrimental effects of high temperatures. For each 5°C increase in temperature, seed storage life will be reduced by half.

Grain Milling

Grain Milling

Milling is the final step in postproduction of paddy. There are three requirements for producing good quality milled rice:

- the starting quality of the paddy is good and at the right moisture content (14%),
- the rice mill is well maintained, and
- the mill is operated by a skilled operator.

If any of these requirements are not met, milling will result in poor quality rice. For instance, milling of poor quality paddy will always result in poor quality milled rice, even if a state-of-the-art mill is used or the miller is experienced. Similarly, the use of good quality paddy by a well skilled operator may result in poor quality rice if the mill is not maintained regularly.

The best quality milled rice will be attained from a mill that has:

- Pre cleaning of the paddy,
- Rubber rollers to remove the husk,
- Effective separation of paddy from brown rice after husking
- Two separate whiteners and one polisher, and
- Grader for the polished white rice.

Main Milling Practices

- **Mill rice at the right moisture content:** 14% MC. If MC is too low, high grain breakage will occur resulting in low head rice recovery. Broken grain has only half the market value of head rice (head rice = 75-100% of whole kernel).

- **Pre-clean paddy before husking:** Use of paddy without impurities will ensure a cleaner and higher quality end product. The more impurities and unfilled grains are present in the paddy, the lower the milling recovery of the rice mill.

  A simple pre-cleaner often used in rice mills contains an oscillating double screen bed with an aspirator. The first screen (7 mm opening or larger) is a scalper that lets through the grain but retains straw. The second screen (1.4

mm opening) retains the grains but lets through broken grains and small stones or weed seeds. The air aspirator sucks out dust and the light empty grains. Air dampers on the blower have to be adjusted to prevent the good grain from being sucked out. The capacity of the paddy pre-cleaner should be based on the capacity of the rice mill. Example: a typical precleaner for a 3 ton/hr rice mill will need to have 5 ton/hr cleaning capacity.

- **Use rubber roll technology for husking:** Engleberg-type or "steel" hullers are no longer acceptable in the commercial rice milling sector, as they lead to low milling recovery and high grain breakage.

The Engleberg-type mill is an adaptation of the "Engleberg" coffee huller from the United States. It is still the mainstay technology for milling parboiled paddy in Bangladesh, and in many African countries. The "iron hullers", or "single pass mills" which all refer to the same mill are notorious for breaking the paddy grain. Because of the high breakage, the total milled rice recovery is 53-55%, and head rice recovery is in the order of 30% of the milled rice. The fine brokens are mixed with the bran and the ground rice hull. This by-product is used for animal feed. In many rural areas, Engleberg mills are used for custom milling the rice requirements of households. The bran produced is left to the miller as the milling fee. The poor performance of the Engleberg mill has led governments to discourage its use and has limited further proliferation.

An example of a rubber roll mill is the compact 2-stage rice mill which has 0.5 to 1 ton per hour paddy input. A typical compact rice mill consists of a 6-inch diameter x 6-inch wide rubber roller husker, and a friction whitener. The friction whitener has a very similar design configuration as the Engleberg except that is has no husking knife. The milling performance of the compact rice mill is superior to the single pass Engleberg huller. Milling recoveries are normally above 60%.

Paddy should be at 14% Moisture content and continuously fed to the rubber rolls. Grain flow rate through the husker is controlled by the feed adjusting valve which is controlled manually or automatically. A clearance of 0.8 to 1.0 mm between the roll surfaces should be maintained to prevent damage to the rolls. This is roughly half the thickness of the paddy grain. The clearance should be adjusted to obtain a husking efficiency of 90 to 95%. The rated husking life of the rubber rolls can vary from 40 to 100 tons, and should be indicated by the manufacturer. Interchanging the left and right roll at mid life will enhance rubber roll life as the rolls will wear out more evenly.

- **Separate all paddy from the brown rice before whitening:** Paddy separation after husking will lead to better quality milled rice, and reduce overall wear and tear on the rice mill. The performance of the rubber roll husker can be expressed by the husking efficiency, which is the % of husked rice in total grain flow. In a properly adjusted rubber roll husker, husking efficiencies can be as high as 95%, however husking efficiencies are often around 80% (i.e. there will be 20% paddy in the output). Besides machine adjustments, uniformity of grain thickness will affect the husking efficiency. If a mixture of varieties is fed into the husker, or paddy grain that did not mature uniformly in the field, husking efficiencies will be lower.

A very simple separator with no moving parts is the screen separator, which can be seen in smaller commercials mills located near rural markets. Brown rice/paddy will move through a number of screens that are set at 31-35° angle. The rough rice moves down the top screen, a mixture of rough rice and brown rice moves down the middle screen and finishing screen, and brown rice will accumulate underneath the finishing screen. Suggested screen sizes are represented in the following table.

Screen Name	Screen size: lateralMesh-number (opening in mm)	Screen size: longitudinalMesh-number (opening in mm)
Top screen	# 5.5 – # 6.0	# 7.5 – # 8.0

Middle screen	# 6.0 - # 7.0	# 7.5 – # 8.0
Finishing screen	# 7.0 - # 7.25	# 7.5 – # 8.0

- **Consider two-stage whitening:** Having at least two stages in the whitening process (and a separate polisher) will reduce overheating of the grain and will allow the operator to set individual machine settings for each step. This will ensure higher milling and head rice recovery.

Installing a 1.4 mm round screen on the outlet of a horizontal friction whitener (as shown), will reduce the amount of small brokens, chips, and germs from the milled rice. The material that falls through the screen can be used to make rice flour.

- **Install a screen sifter** to remove small brokens and chips from the polished rice. Most screens or sieves with a sieve opening not greater than 1.4 mm will be effective in removing small brokens. Rice with a large number of small brokens (or brewer's rice) has a lower market value. The small brokens can be utilized to produce rice flour.

- **Monitor and replace spare parts regularly** to keep milled rice quality high at all times. Turning or replacing rubber rolls, refacing stones, and replacing worn screens regularly will keep milled rice quality high at all times.

- **Do not mix varieties prior to milling:** Different varieties of paddy have different milling characteristics that require individual mill settings. Mixing varieties will generally lead to lower quality of milled rice.

Defining and Measuring Grain Quality

Introduction to Grain Quality

Quality is not always easy to define as it depends on the consumer and the intended end use for the grain. All end users want the best quality that they can afford. The quality of grain is usually the best when it reaches physiological maturity and everything that is done after that point can only cause a decline in quality.

Grain quality is not solely a varietal characteristic but also depends on the crop production environment, harvesting, processing and handling systems. Therefore, maintaining good grain quality is the concern of all disciplines such as breeding, agronomy, entomology, chemistry and engineering.

Defining Quality

Defining Quality for Paddy or Rough Rice

Moisture Content

Paddy is at its optimum milling potential at moisture content of 14%. Moisture content has a marked influence on all aspects of paddy and rice quality and it is essential that paddy be milled at the proper moisture content to obtain the highest head rice yield. Grains with high moisture content are too soft to withstand hulling pressure without undue breakage and may be pulverized. Grain that is too dry becomes brittle and has greater breakage.

Moisture content and temperature during the drying process is also critical as it determines whether fissures and/or full cracks are introduced into the grain structure.

Degree of Purity

Purity is related to the presence of dockage in the grain. Dockage refers to material other than paddy and includes chaff, stones, weed seeds, soil, rice straw, stalks, etc. These impurities generally come from the field or from the drying floor.

Unclean paddy increases the time taken to clean and process the grain. Foreign matter in the grain reduces milling recoveries and the quality of rice and increases the wear and tear on milling machinery.

Varietal Purity

A mixture of varieties causes difficulties at milling and usually result in reduced capacity, excessive breakage, lower milled rice recovery and reduced rice Different sizes and shaped grains makes it more difficult to adjustments the hullers and polishers to produce whole grains. This results in low initial de-hulling efficiencies, a higher percentage of re-circulated paddy, non-uniform whitening, and lower grade of milled rice.

Grain Dimensions

Grain size and shape (length-width ratio) is a very stable varietal property. Long slender grains normally have greater breakage than short, bold grains and consequently have a lower mill rice recovery. The grain dimensions will also dictate to some degree the type of milling equipment needed. As an example, the Japanese designed milling equipment may be better suited to short-bold grains.

Length classification (after hulling)

Classification	Length (mm)	Relation to other factors
Extra long	>7.5	Tends to be fluffy (high amylose)
Long	6.61-7.50	
Medium	5.51-6.60	
Short	< 5.51	tends to be sticky (low amylose)

Grain shape (ratio of length to width on brown rice)

Classification	Ratio
Slender	> 3.0
Medium	2.1-3.0
Bold	1.1-2.0
Round	<1.1

Cracked Grains

Overexposure of mature paddy to fluctuating temperature and moisture conditions leads to development of fissures and cracks in individual kernel. Cracks in the kernel are the most important factor contributing to rice breakage during milling. This results in reduces milled rice recovery and head rice yields.

Immature Grains

The amount of immature paddy grains in a sample has a major affect on head rice yield and quality. The immature rice kernels are very slender and chalky and this results in excessive production of bran, broken grains and brewer's rice. The optimal stage to harvest grain is at about 20-24% grain moisture or about 30 days after flowering. If the harvest is too late, many grains are lost through shattering or dry out and are cracked during threshing, which causes grain breakage during milling.

Discolored/Fermented Grains and Damaged Grains

Damaged grains
Paddy deteriorates through biochemical change in the grain, the development of off-odors and changes in physical appearance. These types of damage are caused from water, insects, and heat exposure.

Yellowing is caused by over-exposure of paddy to wet environmental conditions before it is dried. This results in a combination of microbiological and chemical activity that overheats the grain similar to a milled form of parboiling. These fermented grains frequently possess partly gelatinized starch cells and generally resist the pressures applied during grain milling. While the presence of fermented grain does not affect milling yields it does downgrade the quality of the milled rice because of the unattractive appearance.

The presence of black spots around the germ end of the brown rice kernel is caused by the microorganisms (fungi) and is increased by unfavorable weather conditions. In the process of milling, these black spots are only partly removed which consequently increases the presence of damaged grains.

Defining Quality for Milled Rice

Physical Characteristics

Milling Degree

The degree of milling or percent brown rice removed as bran affects the level of recovery and influences consumer acceptance. Apart from the amount of white rice recovered, milling degree influences the color and also the cooking behavior of rice Unmilled brown rice absorbs water poorly and does not cook well. The water absorption rate improves progressively up to about 25% milling degree after which, there is very little effect.

The flow (frictional property) and packing (bulk density) behaviors of rice are also depend on milling Likewise, the nutrient content of rice is also strongly influenced since most micro-nutrient located largely in the peripheral layers of brown rice are removed with high milling degree.

Head Rice Recovery

The head rice percentage is the volume of weight of head grain or whole kernel in the rice lot. Head rice normally includes broken kernels that are 75-80% of the whole kernel. High head rice yield is one of the most important criteria for measuring milled rice quality. Broken grain has normally only half of the value of head rice. To a large extent, the characteristics of the paddy determine the potential head rice yield although the milling process is responsible for some losses and damage to the grain.

Whiteness

This characteristic is a combination of varietal physical characteristics and the degree of milling. In milling, the whitening and polishing greatly affect the whiteness of the grain. During whitening, the silver skin and the bran layer of the brown rice is removed. Polishing is undertaken after whitening to improve the appearance of the white rice. During polishing some of the bran particles stick to the surface of the rice which polishes and gives a shinier appearance.

Chalkiness

Grain appearance is largely determined by the endosperm opacity and this is commonly classified as the amount of chalkiness. Opaqueness has an overall chalky texture caused by interruption of final filling of the grain. Though chalkiness disappears upon cooking and has no direct effect on cooking and eating qualities, excessive chalkiness downgrades the quality and reduces milling recovery.

Quality standards for milled rice in Philippines (National Food Authority)

Grade Specifications	Grade			
	Premium	**Grade 1**	**Grade 2**	**Grade 3**
Head rice (min %)	95.00	80.00	65.00	50.00
Brokens (max %)	4.90	19.75	34.50	49.00
Defectives				
Damaged grains (max %)	0	0.25	0.50	2.00
Discolored grains (max %)	.50	2.00	4.00	8.00
Chalky and immature grains (max %)	2.00	5.00	10.00	15.00
Red grains (max %)	0	.20	.50	2.00
Red streaked grains (max%)	1.00	3.00	5.00	10.00
Foreign matter (max 5)	0	.10	.20	.50
Paddy (max no./kg)	1	8	10	15
Moisture content (max %)	14.00	14.00	14.00	14.00

Chemical Characteristics

Gelatinization Temperature

The time required for cooking is determined by gelatinization temperature. Environmental conditions, such as temperature during ripening, influence gelatinization temperature. A high ambient temperature during development results in starch with a higher temperature.

Gelatinization temperature is estimated by the extent of alkali spreading and clearing of milled rice soaked in 1.7% KOH at room temperature or at 39 degrees C for 23 hours (Little et al, 1958). The degree of spreading is measured using a seven-point scale as follows:

1. grain not affected
2. grain swollen,
3. grain swollen, collar incomplete and narrow,

4. grain swollen, collar complete and wide,
5. grain split or segmented, collar complete and wide,
6. grain dispersed, merging with collar; and
7. grain completely dispersed and intermingled.

Alkali spreading value corresponds to gelatinization temperature as follows:
- 1-2 high (74.5-80oc),
- 3, high intermediate,
- 4-5, intermediate (70-74oC), and
- 6-7, low (<70oC).

There is normally a distinct preference for rice with intermediate gelatinization temperature.

Amylose Content

Starch makes up about 90% of the dry matter content of milled rice. Starch is a polymer of glucose and amylose is a linear polymer of glucose. The amylose content of starches usually ranges from 15 to 35%. High amylose content rice shows high volume expansion (not necessarily elongation) and high degree of flakiness. The grains cooked dry, are less tender, and become hard upon cooling. In contrast, low-amylose rice cooks moist and sticky. Intermediate amylose rice are preferred in most rice-growing areas of the world, except where low-amylose japonicas are grown.

Based on amylose content, milled rice is classified as
- waxy (1-2% amylose),
- non-waxy (>2% amylose),
- very low (2-9% amylose),
- intermediate (20-25% amylose) and
- high (25-33% amylose).

The colorimetric iodine assay indexes the amylose content of milled rice.

Gel Consistency

Gel consistency measures the tendency of the cooked rice to harden on cooling. Gel consistency is determined by heating a small quantity of rice in a dilute alkali. This test differentiates the consistency of cold 5.0% milled rice paste. Within the same amylose group, varieties with a softer gel consistency are preferred, and the cooked rice has a higher degree of tenderness.

Harder gel consistency is associated with harder cooked rice and this feature is particularly evident in high-amylose rice. Hard cooked rice also tend to be less sticky.

Measuring Quality

Physical Properties of Paddy

Moisture Content of Paddy

Two methods can be used to measure moisture content:

- The primary or direct method (Air oven method)
- The secondary method (Electronic moisture tester)

Air oven method

1. Set the oven at 130°C.
2. Weigh three 100 g paddy samples and place the samples inside the oven.
3. Measure the final weight of the samples after the 16 hours.
4. Compute for the moisture content wet basis (MCWB) using the equation:

$$MCWB = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight} \times 100$$

5. Compute the average MC.

Moisture Tester

1. Read the operators instruction
2. Turn on the moisture meter and ensure that the machine is set for paddy or rough rice.
3. Fill the tray/bowl of the moisture tester with paddy samples.
4. Turn/press the knob until the moisture reading is displayed.
5. Test at least three samples.

Crack Detector

Using the Paddy Crack Detector, count the number of cracked grains in a 100 grain sample then compute the % cracked grains using the equation:

$$\%\ Cracked\ grains = \frac{No.of\ crackedgrains}{100\ grains} \times 100$$

Grain Dimensions

Using the Vernier caliper or photographic enlarger, collect 20 paddy samples at random from each replicate and measure the dimensions to obtain the average length and width of the paddy grains. To obtain the paddy shape, the following equation will be used:

$$Length\ to\ width\ ratio\ (L/W) = \frac{Average\ paddy\ length,\ mm}{Average\ paddy\ width,\ mm}$$

Paddy will be classified based on International Organization for Standardization (ISO) for paddy.

Production practices - effects

- Variety - Length and shape are highly heritable. Grain length and shape are related to head rice yield as long grain varieties tend to break more than short to medium grain during milling.
- Length is little affected by environment, so management has little effect.

Immature Grains

1. Select a 25 gm grain sample

2. Select, segregate and weigh the immature grains in sample. Calculate the percentage immature grains in the sample using the formula:

$$\%\ \text{Immature grains} = \frac{\text{Wt of immature grains}}{\text{Total weight of samples}} \times 100$$

Dockage

Remove light foreign matter, stones, weed and seeds from a 100gm sample. Obtain the total weight then compute the dockage percentage as follows:

$$\%\ \text{Dockage} = \frac{\text{Wt of dockage}}{\text{Total wt of sample}} \times 100$$

1000 Seed Weight

Count and weigh 1,000 grains (paddy).

Physical Properties of Milled Rice

Milling Degree

Milling degree is computed based on the amount of bran removed from the brown rice. To obtain the weight of brown rice, dehull the paddy samples using the Laboratory Huller.

Estimate the percent milling degree using the following equation:

$$\%\ \text{Milling degree} = \frac{\text{Wt of milled rice}}{\text{Wt of brown rice}} \times 100$$

Milling Recovery

Using the Abrasive Whitener, mill the dehulled samples. Compute milling recovery by dividing the weight of milled rice recovered by the weight of the paddy sample.

$$\%\ \text{Milling recovery} = \frac{\text{Wt milled rice}}{\text{Wt of sample used}} \times 100$$

Dockage

Select, segregate and weigh the foreign matter. Record the number of unhulled grains collected from the sample. Determine the percentage of dockage of milled rice using the equation:

$$\%\ \text{Dockage}(mr) = \frac{\text{Wt. of dockage}}{\text{Total wt of milled rice}} \times 100$$

Broken Grain

Using the Grain Grader, separate the broken grain from the whole grains. Compute the percentage of the milling recovery components using the following equations:

$$\% \, Brokens = \frac{Wt \text{ of broken grains}}{Wt \text{ of paddy samples}} \times 100 \quad \% \, Head \, rice = \frac{Wt \text{ of whole grains}}{Wt \text{ of paddy samples}} \times 100$$

Chalkiness

A visual rating of the chalky proportion of the grain is used to measure chalkiness based on the standard Evaluation System SES scale presented below:

Scale	% area of chalkiness
1	less than 10
5	10-20
9	more than 20

Select, segregate and weigh the chalky grains (SES Scale 9). Determine the % chalky grain using the equation:

$$\% \, Chalky \, grain = \frac{Wt \text{ of chalky grains}}{Wt \text{ of milled rice}} \times 100$$

Production practices - effects

- Chalkiness is highly affected by genetics and also by environment - especially high temperature just after flowering. Thus planting date may influence chalkiness.
- The effects of fertility and water management are unknown.

Whiteness

1. Measure the grain whiteness using the Whiteness Meter.
2. Separate and weigh yellow-fermented grains. Calculate the percentage of yellow/fermented grains using the formula:

$$\% \, Yellow \, grains = \frac{Wt \text{ yellow grains}}{Wt \text{ total milled rice}} \times 100$$

Production practices - effects
Discoloration accelerates rapidly when grain is stacked or stored at high MCs.

Grain Shape

Follow the procedure of determining grain shape of paddy. Based on the length to width ratio, the shape of the milled rice will be determined. The ISO Classification is as follows:

$$L/W \, ratio = \frac{Avg. \text{ length of rice}}{Avg. \text{ width of rice}} \times 100$$

Scale	Shape	L/W ratio
1	Slender	Over 3.0
3	Medium	2.1 – 3.0
5	Bold	1.1 – 2.0
9	Round	1.0 or less

1000 Grain Weight

Count and weigh 1,000 whole grains.

Chemical Characteristics of Milled Rice

Amylose Content

Twenty grains are selected and ground in the UDY Cyclone Mill. Amylose content is analyzed using the simplified iodine colorimetric procedure. Samples are categorized into low, intermediate and high based on the following grouping:

Category	%Amylose Content
Low	10-20
Intermediate	20-25
High	25-30

Amylose content and typical characteristics

Term	Amylose content(%)	Characteristics when cooked	Types of products made	Country where preferred
Waxy (or glutinous)	0-2	Absorb little water and therefore have little volume expansion	Rice cakes, desserts, sweets, puffed rice	Staple in RainFed lowlands Laos, N and NE Thailand
Low amylose	8-20	On cooking tend to be moist, sticky and glossy. Split if overcooked. Most japonicas have low amylose	Fermented rice cakes	
Intermediate amylose	21-25	Cook fluffy, remain soft.	Fermented rice cakes	Indonesia, Philippines, Thailand and Vietnam
High Amylose	> 25	Cook dry and	Noodles	Staple - Sri

(See **gel consistency**)		fluffy, become hard when cool. Resist disintegration during boiling.		Lanka, Pakistan, India

Production practices - effects
Amylose content can vary as much as 6% depending upon environmental conditions - High temperatures during ripening lower amylose content, so planting date can be important.

Gelatinization Temperature

Gelatinization temperature is measured using alkali-spreading value. The alkali digestibility test is employed. Grains are soaked in 1.7% KOH and incubated in a 30°C oven for 23 hours. Measurement ranges based on the following:

Category	Temp ranges (°C)	Alkali Spread
Low	55-69	6-7
Intermediate	70-74	4-5
High	75-79	2-3

Gelatinization temperature is the temperature at which the rice absorbs water and starch granules swell irreversibly.

Classification	Gelatinization temperature (GT)	Observations and Implications
Low	< 70°C	Most Japonica varieties have low GT.
Intermediate	70-74°C	Most tropical Indica varieties have intermediate or low GT.
High	>74°C	If very high, then rices become excessively soft and disintegrate when overcooked. Require more cooking and water than rices with lower GT.

Production practices - effects
Variety - GT is highly heritable although it can vary by as much as 10oC within a variety depending upon environmental effects. High temperature after flowering raises GT; low air temperature lowers it.

Gel Consistency

Two to 10 grains are selected and ground separately in the Wig-L Bug. Gel consistency is measured by the cold gel in a test tube, being held horizontally, for one hour.

Measurement ranges and category are as follows:

Category	Consistency, mm
Soft	61-100
Medium	41-60
Hard	26-40

The gel consistency test differentiates rices with high amylose content into three types:

Type	Gel consistency
Very flaky	Hard
Flaky	Medium
Soft	Soft

Gel consistency is genetically determined.

Standards

ISO Standards

International Standards

This International Standard lays down the minimum specifications for rice (Oryza sativa L.) of the following types: husked rice, husked parboiled rice, milled rice and milled parboiled rice, suitable for human consumption, directly or after reconditioning, and which is the subject of international trade.

Normative References

The following standards contain provisions, which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

- ISO 712: 1985, Cereals and cereal products – Determination of moisture content (Routine reference method).
- ISO 950: 1979, Cereals – Sampling (as grain).

Definitions

For the purposes of this International Standard, the following definitions apply.

1. paddy: paddy rice: rough rice: Rice retaining its husk after threshing.
2. husked rice: cargo rice: Paddy from which the husk only has been removed. The processes of husking and handling, particularly of parboiled rice, may result in some loss of bran.
3. milled rice: Rice obtained after milling which involves removing all or part of the bran and germ from the husked rice.

It could further be classified into the following degrees of milling.

- undermilled rice: Rice obtained by milling husked rice but not to the degree necessary to meet the requirements of well-milled rice.
- well-milled rice: Rice obtained by milling husked rice in such a way that some of the germ, and all the external layers and most of the internal layers of the bran have been removed.
- extra-well-milled rice: Rice obtained by milling husked rice in such a way that almost all the germ, and all the external layers and the largest part of the internal layers of the bran, and some of the endosperm, have been removed.

4. parboiled rice: Rice, the starch of which has been fully gelatinized by soaking paddy or husked rice in water followed by a heat treatment and a drying process.
5. glutinous rice: waxy rice: Special varieties of rice (Oryza sativa L. glutinosa) the kernels of which have a white and opaque appearance. The starch of glutinous rice consists almost entirely of amylopectin. It has a tendency to stick together after cooking.
6. size of kernels, broken kernels and chips
   - 6.1 whole kernel: Kernel without any broken part.
   - 6.2 head rice: Kernel, the length of which is greater than or equal to three quarters of the average length of the corresponding whole kernel.
   - 6.3 large broken kernel: Fragment of kernel, the length of which is less than three-quarters but greater than one-half of the average length of the corresponding whole kernel.
   - 6.4 medium broken kernel: Fragment of kernel, the length of which is less than or equal to one-half but greater than one-quarter of the average length of the corresponding whole kernel.
   - 6.5 small broken kernel: Fragment of kernel, the length of which is less than or equal to one-quarter of the average length of the corresponding whole kernel but which does not pass through a metal sieve with round perforations 1.4 mm in diameter.
   - 6.6 chip: Fragment of kernel which passes through a metal sieve with round perforations 1.4 mm in diameter.
7. extraneous matter: Organic and inorganic components other than kernels of rice, whole or broken
8. heat-damaged kernels: Kernels, whole or broken , that have changed their normal color as a result of heating. This category includes whole or broken kernels that are yellow due to alteration. Parboiled rice in a batch of non-parboiled rice is also included in this category.
9. damaged kernels: Kernels, whole or broken, showing obvious deterioration due to moisture, pests, disease or other causes, but excluding heat-damaged kernels (3.8).
10. immature kernels: Kernels, whole or broken, which are unripe and/or underdeveloped.

11. chalky kernels: Kernels, whole or broken, except for glutinous rice, of which at least three-quarters of the surface has an opaque and floury appearance.
12. red kernels: Kernels, whole or broken, having a re coloration covering more than one-quarter of their surface, but excluding heat-damaged kernels (3.8).
13. red-streaked kernels: Kernels, whole or broken, with red streaks, the lengths of which are greater than or equal to one-half of that of the whole kernel, but where the surface covered by these red streaks is less than one-quarter of the total surface.
14. pecks: Kernels, whole or broken, of parboiled rice of which more than one-quarter of the surface is dark brown or black in color.
15. other kinds of rice
    - 15.1 Paddy in husked rice, in husked parboiled rice, in milled rice and in milled parboiled rice.
    - 15.2 Husked rice in husked parboiled rice, in milled rice and in milled parboiled rice.
    - 15.3 Milled rice in husked parboiled rice and in milled parboiled rice.
    - 15.4 Glutinous in non-glutinous rice.

Specification

1. General, organoleptic and health characteristics
    - Kernels of rice, whether or not parboiled, husked or milled, and whether or not whole or broken, shall be sound, clean and free from foreign odors or odor which indicates deterioration.
    - The levels of additives and pesticide residues and other contaminants shall not exceed the maximum limits permitted by the national regulations of the country of destination or, in their absence, by the joint FAO/WHO Commission of Codes Alimentarius.
    - The presence of living insects, which are visible to the naked eye, is not permitted.

2. Physical and chemical characteristics
    - The moisture content, determined in accordance with ISO 712, shall be not greater than 15% (m/m)
      NOTE: Lower moisture contents may be required for certain destinations depending on the climate, duration of transport and storage. For further details, see ISO 6322, parts 1, 2 and 3.
    - The maximum contents of extraneous matter, defective kernels and other kinds of rice in husked and milled rice, whether or not parboiled, and determined in accordance with the method described in annex A, shall be not greater than the values specified in table 1.
    - All commercial contracts should be clearly the total percentage of broken kernels permitted, classified according to the agreed categories, and the relative proportions of each category, and the total percentage of extraneous matter and of defective kernels, determined in accordance with the method described in Annex A.
    - The proportion of chips shall not exceed 0.1%.

ISO 7301 standards for rice

Defect	Reference to the definition	Husked rice (%)	Milled rice (non-glutinous) (%)	Husked parboiled rice (%)	Milled parboiled rice (%)
Extraneous matter *organic* *inorganic*	7	 1.5 0.5	 0.5 0.5	 1.5 0.5	 0.5 0.5
Paddy	1	2.5	0.3	2.5	0.3
Husked rice	2	-	1.0	-	1.0
Milled rice	3	-	-	2.0	2.0
Heat-damaged kernels	8	4.0	3.0	8.0	6.0
Damaged kernels	9	4.0	3.0	4.0	3.0
Immature kernels	10	12.0	2.0	12.0	2.0
Chalky kernels	11	11.0	11.0	-	-
Red kernels	12.0	12.0	4.0	12.0	4.0
Red-streaked kernels	13.0	-	8.0	0	8.0
Glutinous rice	5.0	1.0	1.0	1.0	1.0
Pecks	14.0	-	-	4.0	2.0

1.

Philippine Standards

Philippine Standards

Type topic text here.

References for Rice Quality

- Mackill, D.J., Coffman, W.R., and Garrity, D.P. 1996. Rainfed Lowland rice improvement. International Rice Research Institute, P.O., Box 933, Manila, Philippines. 242 p.

Rice Byproduct Utilization

Why Use Rice Byproducts?

With an increase in crop yields and cropping intensity, the management of rice by-products is becoming a problem as well as an opportunity. In traditional rice cropping systems, rice straw was either removed from the fields at harvest time and stored as stock feed, or burnt in the fields. Similarly rice husks were either returned to the field after milling or burnt. Concerns over air quality, in particular the release of particulate matter into the air during burning, have brought about efforts to restrict burning in many countries. When by-products are not burnt, changes in residue management at field level or off-farm uses must be found to overcome the problem.

There are many good reasons for using rice byproducts:

- they contain energy
- they are a renewable resource
- their utilization can reduce waste problems and related environmental pollution
- they are carbon neutral i.e. no net emission of CO_2 in the atmosphere

Of the many possible uses for rice byproducts, the ones presently most likely to be economic include:

- Rice straw as an in-field means of maintaining soil organic matter levels,
- Rice straw as a low grade animal feed in areas with no other feed options,
- Rice straw as a mulch in high value crops,
- Rice hulls as a fuel source, and
- Bran as a source of oil
- Brewer's rice and small brokens as a source of flour.

Rice Byproducts Properties

Rice Straw Properties

Rice straw is generated in the field during harvesting.

- The quantity of straw can vary from 2 tons/ha to more than 8 tons/ha, and will depend on the variety of rice, productivity (high rice yield will result in high straw yield), and harvesting method (cutting closer to the ground will result in more straw). Total straw available in the field is proportional to grain yield. The straw to grain ratio typically varies from 0.8:1 to 1.2:1
- The length of straw varies by variety and harvesting method, and ranges from 30-120 cm
- At harvest, the moisture content of straw is usually more than 60% on a wet basis (i.e. more than half is water), however in dry weather straw can quickly dry down to its equilibrium moisture content of around 10-12%.
- The bulk density of dry rice straw is around 75 kg/m3 for loose straw, and 100 to 180 kg/m3 in packed or baled form. In comparison, the bulk density of paddy grain is 500-650 kg/m3 depending on moisture content. In packed or baled form, straw bales take up at least three times the amount of space as wood logs for the same amount of weight.

- In packed form, rice straw has low thermal conductivity, i.e. it is a good insulator. Packed or baled rice straw also has good fire-resistant characteristics.
- Rice straw has a high ash content (up to 22%) and low protein content. As a result, rice straw does not decompose as readily as other straw from other grain crops such as wheat or barley.
- Rice straw is more resistant to bacterial decomposition than other materials and therefore more suitable to serve as building material
- The calorific value (measure of how much energy is contained in the material) of rice straw is 14-16 MJ/kg on a 14% moisture content basis. In comparison, most dry woods contain 18-20 MJ/kg, and coal contains 25-30 MJ/kg. The higher the ash content of the straw, the lower the calorific value.
- The main carbohydrate components of rice straw are hemicellulose, cellulose and lignin.
- Rice straw contains moderate levels of potassium and chlorine, which reduces the melting temperature of straw ash to approximately 750 to 900ºC meaning increased "Slag" (molten glass) deposits when straw is used as a fuel.

Rice Hull or Husk Properties

Rice hulls are generated during the first stage of rice milling, when rough rice or paddy rice is husked i.e. husk is separated from the rest of the grain.

- In general, 100 kg of paddy rice will generate 20 kg of hulls. Short grain varieties produce slightly more hull than medium or long grain varieties.
- Moisture content of rice hull is around 10%; the equilibrium moisture content is lower than that of paddy or rough rice.
- Bulk density of rice hulls is 100 to 150 kg/m3. If rice hulls are ground, bulk density increases to 200 to 250 kg/m3.
- Rice hull contains 16 to 22% ash, and 90-96% of the ash is composed of silica. Therefore, rice hull ash can be considered a slightly impure form of silica.
- The ash composition and structure give rice hulls an abrasive character. Metal surfaces in frequent contact with rice hulls will wear out and eventually puncture.
- The calorific value of rice hull is 14-16 MJ/kg on a 10% moisture content basis. In comparison, most dry woods contain 18-20 MJ/kg, and coal contains 25-30 MJ/kg. The higher the ash content of rice hulls, the lower the calorific value.
- The main carbohydrate components of rice hulls are cellulose and lignin.
- Rice hulls contains only minor levels of potassium and chlorine, and therefore ash melting temperatures of rice hull are much higher than those of rice straw. Thus, you have less problems of "slag" (molten glass) deposits when hull rather then straw is used as a fuel.

Rice Bran Properties

Rice bran is generated during the rice milling process. From a nutritional point of view, it is the most valuable byproduct. Rice bran consists of the outer layers (pericarp,aleurone, germ, and part of the endosperm) of the rice kernel that are removed during whitening and polishing of husked rice. When paddy is handpounded or milled in a one-pass Engleberg steel huller, rice bran is not produced separately but mixed with rice hulls.

- Out of 100 kg paddy rice, 5 to 8 kg of bran can be typically produced.
- Moisture content of rice bran is in the 10 to 15 % range, on wet weight basis
- Rice bran is a mixture of substances, including protein, fat, ash, and crude fiber. In many cases, bran contains tiny fractions of rice hull, which increases the ash content of bran.
- Bran composition is largely dependent on the milling process. In modern rice mills, several different kinds of bran are produced: coarse bran (from the first whitening step), fine bran (from second whitening step) and polish (from the polishing step). Polish consists of part of the endosperm and is often referred to as meal.
- Rice bran has a high nutritive value. Besides proteins, rice bran is an excellent source of vitamins B and E. Bran also contains small amounts of anti-oxydants, which are considered to low cholesterol in humans.
- Rice bran contains 10-23% bran oil. The oily nature makes bran an excellent binder for animal feeds. Bran oil, once stabilized and extracted, is a high quality vegetable oil for cooking or eating.
- Rice Bran has a wide particle size distribution, with majority of particles in the 0.1 to 0.5 mm range. The particle size distribution is strongly affected by the milling conditions.

Rice Flour Properties

Rice is consumed largely as a whole grain. During the processing of rice, some breakage occurs and smaller pieces of the broken rice kernels are used for grinding into rice flour, or for beer brewing.

- Rice flour contains primarily starch, and variable amounts of protein (~6%), fat (~2%), and ash (~1%). The actual composition depends on the rice variety from which the flour originated.

- The main difference between rice flour and wheat flour is the absence of gluten in rice flour. Gluten is the main structure-forming protein in bread. Gluten affects the texture of bread i.e. its “softness” or “hardness”. In general, short- and medium-grain rice flour can produce soft-textured breads, but long-grain rice flour yields sandy, dry bread crumbs.

- Flour properties are further evaluated by a so-called amylograph pasting curve which displays the viscosity of rice flour paste as it is heated and subsequently cooled (a paste is made by mixing 10 to 20% of rice flour in water). This technique is used to characterize rice varieties that give different texture results in breads made from rice flour. For instance, IR8 has a low gelatinization temperature (see also rice quality module) which is favorable for baking, but a high final viscosity wich adversely affects bread texture. As a result, bread made from IR8 has a dry, crumbly texture within 24hr after baking. The flour properties of rice flour are closely related to the amylose content of the rice (see rice quality module)

Source: Rice Processing and utilization, Bohr S. Lu, Encyclopedia of Agricultural Science Vol 3, Academic Press, 1994.

Rice Byproduct Uses

Rice Byproduct Uses

Traditional uses of rice byproducts includes straw and hull for energy, animal feed, and building materials. The byproducts of the one-pass Engleberg rice mill (a mixture of ground rice hulls and bran) are often used as feed for chickens or other small animals. Various factors will dictate whether byproducts are used or not. In India, straw and hull are widely used for feed, cooking fuel, and roofing material. Here population pressure, rural poverty, and limited access to fuel wood results in the extensive use of rice byproducts. In Bangladesh, rice hull briquettes are now commonly used as cooking fuel. Use of the briquettes is encouraged by increasing prices of conventional cooking fuels, the wide availability of rice hull, and low cost technology for converting hulls into briquettes.

In order to evaluate the feasibility of a technology or system in any given situation, the following issues should be addressed:

- the quantity and quality of byproduct needed for successful utilization;
- the efficiency of the process i.e. how much energy or product can be produced out of a unit of byproduct;
- the marketability of the product such as the price of alternative fuels or products, fluctuation of prices, etc;
- the amount of capital necessary for acquiring and installing the technology;
- operating costs of the technology such as fuel, labor, and electricity costs;
- other issues not directly affecting the cost (i.e., referred to as externalities), such as environmental impact (smoke, noise, etc.) of the technology.

Rice Straw Uses

In-Field Straw Management

Stubble Incorporation

Straw decays most readily in the presence of moisture and oxygen. Straw decays fastest when it is incorporated into a soil that has a moisture content at about 60% of the water holding capacity and temperatures above 25°C. In these aerobic (with oxygen) conditions, microbes decompose straw into organic matter, minerals and carbon dioxide.

Straw also breaks down in anaerobic (without oxygen) conditions. This process is much slower and results in the production of methane, hydrogen sulfide and organic acids. Different microbes are at work under anaerobic and aerobic conditions. Chopping the straw into smaller pieces and incorporating it into the soil enhances the process of decomposition. If the material is left on the surface, it needs to be evenly spread and chopped into small pieces (1-10cm length) to enhance the flow of tillage implements and reduce equipment blockages. When fields are double cropped or there is insufficient moisture or time for straw to decay naturally, the straw must be chopped and evenly spread on the surface.

Stuble Mulching

Rice straw can be used as mulch for rice or for other crops. Mulch reduces evaporation from the soil, increases water infiltration and protects the soil against erosion (the latter being especially important on sloping land). Relatively more residue is required to reduce evaporation than to reduce erosion. While the rates depend on soil type and slope, typical amounts of residue required to reduce both water and wind erosion range from 1-2.5 t/ha. By contrast rates of >8 t/ha straw residue can be required before significant reductions in evaporation occur, and then the benefits may only be short term (e.g., 1 month).

Stubble Composting

Field composting is increasingly used in some areas to recycle rice straw nutrients back to the field. While rice straw composition of major nutrients is rather poor, the amounts of K can be significant (see table). For example, for every 1 t of straw (dry weight) returned to the field, there will be between 5-8 kg N, 0.5-1 kg P, 13-20 kg K, 5-1 kg S, 0.3-1.7 kg Ca and 1.5-1.6 kg Mg added to the soil. It is clear that straw can be a significant source of K. Thus a t/ha crop may produce of the order of 4 t straw meaning: 20-32 kg N, 2-4 kg P, 52-80 kg K, 2-4 kg S, 1.2-6.8 kg Ca and 6-7.2 kg Mg are added back to the soil.

Table: typical rice straw composition of major nutrients:

	N	P	K	S	Ca	Mg
Straw %	0.5-0.8	0.05-0.1	1.3-2.0	0.05-0.1	0.03-0.17	0.15-0.16

Open Field Burning

In many cases, open field burning of rice straw is the most cost-effective method farmers have for straw management. While straw burning is still practiced in many countries, it is increasingly becoming unacceptable because of environmental and health concerns. When stubble is burnt, air is polluted through emissions of particular matter, carbon monoxide, methane, hydrogen, hydrogen chloride, poly aromatic hydrocarbons, nitrogen oxides and biogenic silica fibres. Prolonged exposure to some of these pollutants can be hazardous to humans.

Straw Collection Systems

Field-collection systems for rice straw include swathing, raking, baling, roadsiding, truck loading, and road transport. Since straw collection costs are inversely proportional to the straw yield (i.e., the more straw collected from a field, the lower the collection costs per ton of straw) it is recommended to cut the straw as low to the ground as possible prior to baling. Common bales for rice straw include small rectangular bales, large rectangular bales ("Hesston" bales), or round bales. The type of bale is often dictated by the end-users: small rectangular bales for straw-bale houses, large rectangular bales for energy production, and round bales for use as animal feed. The advantage of large bales is a higher bale density (i.e. lower transportation costs and less space needed for storage), however larger bales require use of heavier machinery that can bog down in harvested rice fields.

Off-Field Straw Use

Animal Feed

Rice straw has a low nutritive value as feed, owing to its low protein, high ash, and high silica content. It is often used as an animal feed by in-field grazing during the fallow period, or as livestock feed when the harvested crop has been threshed at a centralized location. Rice straw for animal consumption should be stacked or baled at low moisture levels (10-12%) and kept under shelter to avoid the infestation of straw with mold-developed toxins.

Supplements such as molasses and urea are added to the straw to increase the digestibility of rice straw. Typical rates are 5 kg of molasses/urea per 100 kg of dry matter.

There are some commercial initiatives to enhance the feed quality of rice straw by adding nitrogen and removing ash/silica, the status of commercialization is unknown. The high silica content of straw can cause excessive wearing of animal teeth.

Fuel

Combustion
Rice straw can be used as a fuel source for combustion in furnaces and boilers for driving steam turbines to generate process steam and electricity. The efficiency of energy conversion for most conventional combustion systems is about 20 to 25%. As each kilogram of straw or husk contains 14MJ of energy, 1.2 kg of straw has the potential to produce 1 kW-hr of electric power. The efficiency further depends on parasitic load of the plant (i.e. how much energy is used by the powerplant itself), and straw moisture content.

Straw contains potassium, sodium and chlorine, which may cause problems of slagging, fouling, and corrosion in boilers and furnaces. This occurs because even moderate levels of potassium (2-3%) reduce the melting point of silica from above 1700°C down to 800 -1000°C. As most furnaces normally operate in this temperature range, fouling and slagging occur. Fouling and slagging will lead to build-up of glassy deposits in the boiler, requiring frequent shutdowns for maintenance. Chlorine corrodes metallic surfaces such as heat exchangers which lead to high maintenance costs. Potassium, sodium and chlorine can be leached from the straw at extra cost. It takes at least 4 hours of leaching with water or 100 mm of rainfall with water to reduce the potassium levels to an acceptable level. Besides fouling and corrosion problems, use of rice straw as fuel on a large scale faces the problems of the costs of collecting, transporting and storage. Baling and gathering costs range from $15-30/ ton, and costs are dependent on straw yield and type of the collection system.

In Denmark and the United Kingdom, small powerplants (10 to 30 MW electricity) have been established that use straw from other cereal crops such as wheat and barley - which do not have the same high levels of potassium, sodium or chlorine. In these countries, governmental support through subsidies, tax incentives or mandates have created advantageous circumstances for the commercial development of straw-to-energy conversion. In colder climates, straw can be used in farm-level combustion systems for heating of buildings. There are more than 1000 biomass fired power plants in USA, however rice straw has been excluded as fuel because of higher maintenance costs.

Gasification

Thermo-chemical gasification involves burning biomass without sufficient air for full combustion, but with enough air to convert the solid biomass into a gaseous fuel. The gas (often referred to as producer gas) can be used in internal combustion engines to replace diesel or gasoline, as fuel for heating, or cooking. It should be noted that the gas should be handled in an appropriate manner given its high carbon monoxide content.

Rice straw can be used to generate "producer" gas by heating the material to 400-500°C in a gasifier reactor. "Producer" gas consists of a mixture of gases including methane, hydrogen and carbon monoxide. The by-product of gasification is char which is produced in the gasifier and must be periodically removed. Most gasification systems have energy efficiencies of about 30%. Problems may occur if the gas mixture is not sufficiently cleaned or scrubbed to remove the tar. Tar forms when hydrocarbons contained in the gas condense and this causes mechanical problems through gumming up the engine heads and valves. Tar must also be disposed in a safe manner.

The gas output of these systems range from 100-300 kg/m2/hr and most gasifiers are connected directly to an engine. A 75 kW diesel engine requires approximately 20 l diesel per hour. This would be equivalent to burning 80 kg of rice straw/husk or 60 kg of wood per hour. Recent developments in gasification and gas clean-up technology have shown that gas produced from biomass can be competitive with generators that are coupled to diesel engines. In China, there are some implementations of pipeline distribution of thermal gas for household cooking.

Biogas

Small-scale biogas digesters have been widely deployed in China, India, Nepal, and other Asian countries. Most of the biomass from human and animal waste, landfill waste, and crop residues can be converted into biogas. The exception is the biomass component lignin (a major component of wood, but only a minor component of rice byproducts) which can not be converted to biogas. Anaerobic digestion is a microbial decomposition process that is relatively slow, however the main advantage is it does not require a lot of maintenance.

Fermentation by anaerobic bacteria is used to produce biogas which contains methane, carbon dioxide, water and small concentrations of hydrogen sulfide. Production of biogas is also referred to as bio-gasification or bio-methanation and is used in municipal waste water treatment or animal manure processing. For anaerobic digesters to function properly, the feedstock (i.e. fuel source) should have a carbon to nitrogen ratio of approximately 30:1. Rice straw has a carbon to nitrogen ratio of 80 -100:1. Therefore to attain the correct ratio a source of nitrogen such as manure must be added. Typical energy efficiencies are around 25%. Depending on the source of manure between 2.5-20kg of material must be digested to produce 22-24 MJ/m3. Chicken and pig manure are superior to cattle manure for gas production. The hydrogen sulfide contained in biogas is highly corrosive in combustion engines and must be removed by scrubbers for long term use.

A significant advantage of anaerobic digestion is its byproduct: sludge. Sludge is a valuable fertilizer in particular when it is dried.
Liquid Fuel
Ethanol is produced by fermentation of sugars and is the predominant liquid fuel derived by biochemical means from biomass. Ethanol is normally used as a blending agent with gasoline from 10-12% in conventional gasoline engines, or as primary fuel in modified internal combustion engines. Currently most of the fuel ethanol in the world is produced from corn (USA) or sugar cane (Brazil).

About 60% of rice straw is composed of hemi-cellulose and cellulose, which can be converted into ethanol, provided that straw is pretreated through acid or enzymatic hydrolysis. One ton of rice straw is capable of producing 300 l of ethanol. The equivalent weight of corn would produce 400 l. Ethanol contains 29.9 MJ/kg (21 MJ /l) while gasoline contains 44MJ/kg (34 MJ/l). Corn grain or sugar cane are the preferred materials for ethanol production, as hydrolysis is not required. In recent years, commercial energy companies have stepped up research and development efforts into ethanol production from ligno-cellulosic biomass including straw, however no plants have yet been installed beyond the pilot stage. Currently two plants have been proposed to produce ethanol from rice straw in California. As with most renewable energy options, incentives should be in place so ethanol from biomass can compete with regular liquid fuels.

Fiber/Construction Material

Straw can be used as wall materials in the construction of houses or for manufacturing particleboard. The advantage of using straw is its excellent insulation characteristics, which can reduce costs for space heating. As a 300 m2 house requires 5-600 bales or 1.2 tons of compacted rice straw to construct the outside walls, straw as construction material represents a very small market.

Straw has also been used to produce particleboard for use in house construction and furniture manufacturing. Artisans have found the material hard to work and the high silicon levels causes excessive wear and tear on equipment. There are several straw board manufacturing plants in the United States, but none of them uses rice straw. Although commercial initiatives for rice straw-derived particleboard are on-going, straw board has not yet been able to compete with board made from wood waste. Important constraints are the need for energy-intensive grinding of straw into smaller particles, and large amount of space needed for storage (given the low bulk density of straw, even in baled form).

Rice Straw for Fiber/Paper

Straw can be an important source of raw materials for the production of paper. Cereal straw, in particular wheat straw, is a major source of pulp for paper production in China and other Asian countries. The high silica content of rice straw (9-14%) however prohibits the economic use of rice straw for this purpose. The silica will cause problems in the recovery of chemicals used in the pulping process. For rice straw, there is currently no commercially available solution for this problem. Other problems with the use of straw for pulp are the higher water retention capacity of straw, the lower yield per ton of raw material compared to wood (straw yields 45% of pulp whereas wood yields 55% pulp), and the low bulk density of straw.

Rice Straw for Erosion Control/Soil Amendment

Rice straw is being used in bales or waffle pods for erosion control, reclamation areas and re-establishment of denuded areas following civil works such as road construction. This use is limited by the transportation costs of the straw, and the small volumes used in the erosion control methods. In California, highway contractors are required to use rice straw materials for erosion control purposes.

Rice Hull or Husk Uses

Availability of Rice Hulls
The availability of rice hulls varies from country to country and from location to location. Rice hull availability depends on the type and size of the rice mills, and their locations. Larger rice mills that are located in or close to urban areas will have more disposal problems with hulls compared to smaller village-type rice mills located in rural areas. In addition, some rice mills operate only a few months out of the year, whereas others operate throughout the year. Finally, restrictions on open-pile burning affect the availability of hulls as well.

In most rice mills rice hulls are separated from husked rice through aspiration, as rice hulls are lighter in weight than husked rice. In some rice mills, hulls are ground prior to piling or storage. Grinding makes it easier to transport hulls in suspended air, reduces space needed for storage, and reduces transportation costs.

Rice hull as Animal feed
Rice hull has traditionally been used as an ingredient in ruminant and poultry feeds. Currently, commercial feeds may contain up to 5% to 10% of ground rice hulls. Feeding ground rice hulls directly as roughage to cattle, hogs, and horses is a common practice in many countries, although rice hulls have low digestibility and nutritive value. Of all cereal by-products, the rice hull has the lowest percentage of total digestible nutrients (less than10%). Like rice straw, adding a source of nitrogen can enhance rice hulls as a feed source. Rice-mill feed is a mixture of rice hulls and other rice milling byproducts and is an acceptable component of animal feeds. The feed value of rice-mill feed is higher because of the presence of rice bran and polish in the feed. The byproduct of the Engleberg-type rice mill is an example of such a feed as it consists of a blend of ground rice hull, bran and polish. Constraints for rice hull use as feed are low digestibility, its peculiar size, low bulk density, high ash/silica content, and abrasive characteristics.

Rice hull as fertilizer
Rice yields can be improved over and above yields obtained with regular use of fertilizer by addition of rice husk ash. Rice hull can also serve as a moisture retention helper or as a weed growth inhibitor in a soil. When rice hull is burned, the remaining ash can serve as a mix for fertilizer as was done traditionally in China, and is currently practiced in Bangladesh, Vietnam and other countries where rice hull is used as a domestic fuel. Finely ground rice hulls are also used as component in commercial mixed fertilizers. The rice hull prevents caking of other fertilizer components. In Japan, farmers have been using carbonized (partially burnt) rice hulls as soil conditioner for a long time. To what extent the current restrictions on pile burning have limited this use, is unknown.

Worms can play a key role in rice hull decomposition, as rice hulls can be difficult to compost, with their low **C:N ratio**, their high **cellulose** and **lignin** content, and their waxy surface cover that impedes microbial attack, due to its low capacity to absorb water. Using composts made by mixing rice hulls with manure contributes micronutrients and improves soil structure (more water and air retention).

References: **http://www.agroecology.org/cases/ricehullcompost.htm;**

Fuel: Rice hull combustion
Rice husks are a much more economic material for direct combustion compared to rice straw. Husks do not contain the same levels of potassium or chlorine, therefore they do not require leaching before use. Husks are generated at a central location at the rice mill and can be easily transported. Husks also produce higher purity ash that can be used in iron furnaces and cement. Approximately 30% of the husk ends up as ash which presently has a retail value of $200 per ton. In the USA, the cost of installing an electrical power plant, which uses rice husks, is approximately $1 million per MW of electric power capacity. Such a power plant will require 1.5-2.0 tons of husk for each MW hour of electricity produced. Production costs are 2-3 cents per kWhr and the power plant will consume about 10% of the power produced for its own needs. In California, rice hull is used as a fuel for electricity generation in medium sized (25 - 50 MWe) combustion facilities.

In the modern rice milling industry, rice hulls are used as fuel source for grain drying and parboiling. In Thailand, rice is dried in high-temperature fluidized bed dryers, and drying heat is provided by cyclonic rice hull furnaces. In Arkansas, about 30% of rice produced is parboiled, and heat for process steam and rotary grain dryers is produced from rice hulls. In Bangladesh, rice hulls are the preferred fuel for parboiling, and rice hulls are widely used for grain drying in the larger rice mills in Northern India.

At the domestic level, rice hull can be briquetted to improve combustion characteristics and ease of handling. Extruder technology for rice hulls that originated in Korea and is now common in rural Bangladesh.

Fuel: Rice hull gasification
The gasification of rice hulls to produce a combustible gas can have several objectives: direct combustion in boilers or furnaces, combustion in Internal Combustion (IC) engines, or production of cooking gas. Gas produced in gasifiers (commonly referred to as " producer gas") for use in boilers and furnaces is a technically and economically proven technology, and provides a more efficient type of energy conversion than direct combustion of rice hull. Technologies for combustion in IC engines were developed in a number of countries (China, Italy, Thailand, India, U.S.A.), and this is technically feasible for both diesel and gasoline-fueled engines. Large Italian rice mills have traditionally gasified their rice husks and used the gas to drive power units for milling. However, considering the volume of production of rice hull in the world and the wide use of IC engines, use of this technology is not widespread. A limited number of small-scale rice hull gasifiers (5 - 20 kW) are in use in Northern-India for generation of electricity and irrigation water pumping.

Industrial use of Rice hull and Rice hull ash
Given the high silica content of rice hull ash, rice hull ash is used as industrial commodity in the steel industry. It is used as an insulator during steel

manufacturing, to prevent rapid cooling of steel and ensure uniform solidification. Prices for rice hull ash on the world market are approximately $200 per ton of ash (equivalent to $ 40 per ton of rice hulls, or $ 8 per ton of rough rice). Using rice hull ash in the cement industry is currently considered as well. Other reported industrial uses of rice hull include use of rice hulls in ceramic bricks, refractory, furfural, abrasives, and sodium silicate.

Rice Bran Uses

Prospective Uses of Rice Byproducts

The conventional use of rice bran is as ingredient for animal feeds, in particular ruminants and poultry. In recent years however, advances in stabilization techniques have been made which has led to new uses for bran and its derivatives, most notably bran oil for cooking and waxes for cosmetic products. In the developing countries, rice bran is underutilized due to a lack of suitable stabilization techniques.

Rice Bran Stabilization

The key to successful use of rice bran is stabilization. Upon milling, bran will be exposed to enzymes from the outer layers of the rice kernel, resulting in hydrolysis of bran oil, a major component of the bran. This in turn will lead to rancidity of the bran which will give it an acid taste, hence rendering it unsuitable for consumption by humans. Techniques for bran stabilization include cold storage, chemical stabilization, irradiation, and heat stabilization (either through direct heat or microwave). Heat stabilization is the most common method and has additional advantages of simultaneously killing bacteria, molds, and insect eggs.

Rice Oil Production

Edible rice oil is a liquid that is derived through stabilization and extraction of bran oil. Rice oil is used as a household salad oil and cooking due to its plain, good taste, as well as favorable oxidation characteristics. It is also used commercially in the production of mayonnaise and dressings. Due to its heat stability, it is widely used in Japan as oil for frying potato chips and other snacks. The byproduct of stabilization is called dark oil, which is used as an additive in production of commercial feeds.

After stabilization of bran, bran undergoes an intricate industrial extraction process that includes pre-treatment (sifting of impurities), steaming, solvent extraction, de-acidification, and de-waxing.

Cosmetic Products from Rice Bran

Traditionally, Rice bran was used to prepare vitamin-B concentrates. The development of synthetic vitamins has greatly reduced use of bran for this purpose. Currently, many cosmetic products are available that are to some extent based on rice bran extracts. The development of these products is largely driven by the demand for non-artificial, "nature-based" products. Commercial cosmetics that use rice bran include face waxes, soaps and oils.

Rice Flour Uses

- Flour made from broken grain is used in a variety of food products including breakfast cereals, and snack foods. Rice flour is also used in composite flours for baking i.e. blends of up to 20% of rice flour into wheat flours.

- Baby cereal: Precooked rice cereal is frequently prescribed as the infant's first solid food. Precooked rice cereal is produced by preparing and cooking a slurry, and subsequently drying the slurry in drum drier. Extrusion-cooking is also used. Ingredients added during the manufacturing of baby cereal include sugar, iodized salt, sodium and iron phosphates as well as amino acids. Rice cereal will become rancid if packaged in a hermetically sealed container. The package material most suitable for keeping rice cereal is one that allows for transmission of moisture vapor and gas, such as paperboard cartons.

- Thickening agent: Rice flour from waxy/glutinous rice is used as thickening agent for sauces, puddings and oriental snack foods.

Terminology in Grain Quality

Brown rice or husked rice - is the least processed form of rice. It has the outer hull removed, but still retains the bran layers that give it that characteristic tan color and nut-like flavor. The outer layer of the bran gives this rice a chewier texture than white rice.

Chalkiness - if part of the milled rice kernel is opaque rather than translucent, it is often characterized as chalky. Chalkiness disappears upon cooking and has no effect on taste or aroma, however it downgrades milled rice. Cause of chalkiness is interruption during the final stages of grain filling.

Head rice - milled rice with length greater or equal to three quarters of the average length of the whole kernel

Head rice recovery - weight percentage of head rice (excluding brokens) obtained from a sample of paddy. Can be specified on paddy (ISO standard) or on milled rice basis

Large brokens - milled rice with length less than three quarters but more than one quarter of the average length of the whole kernel
the husked rice

Milling degree - a measure of the amount of bran removed from the brown rice

Milling recovery - weight percentage of milled rice (including brokens) obtained from a sample of paddy.

Milled rice - rice after milling which includes removing all or part of the bran and germ from
Modern rice milling process consists of:

- pre-cleaning - removing all impurities and unfilled grains from the paddy
- husking - removing the husk from the paddy

- husk aspiration - separating the husk from the brown rice/unhusked paddy
- paddy separation - separating the unhusked paddy from the brown rice
- destoning - separating small stones from the brown rice
- whitening - removing all or part of the branlayer and germ from the brown rice
- polishing - improving the appearance of milled rice by removing remaining bran particles and by polishing the exterior of the milled kernel
- sifting - separating small impurities or chips from the milled rice
- length grading - separating small or large brokens from the head rice
- blending - mix head rice with predetermined amount of large or small brokens, as required by the customer
- weighing and bagging - preparing milled rice for transport to the customer

Parboiled rice - rough rice which has been subjected to a steam or hot water treatment prior to milling. Parboiling increases the percentage of head rice and the vitamin content of milled rice. This procedure gelatinizes the starch in the grain, and results in firmer more separate grains. It also takes longer to cook.

Red rice - an annual grass, adapted to an aquatic habitat, that reproduces by seed. The leaves have short, stiff hairs on their upper and lower leaf surfaces. The plants tiller profusely, becoming brushier than white rice plants. Panicles are loose and open and droop slightly. The grain shatters easily when ripe. The many types include those with short, medium, or long grains; those with straw-colored, red, or black hulls; and those with short or long awns on the spikelet.
Rough rice - similar term for paddy, or rice retaining its husk after threshing

Small brokens or "brewers rice" - milled rice with length less than one quarter of the average length of the whole kernel.

Total milled rice (polished rice) - bulk of the starch endosperm consisting of head rice, second heads, screenings, and brewers' rice.

Whiteness - a measure of the color of milled rice. A result of milling degree, varietal characteristics and postharvest handling (see also yellowing).

Whole kernel - milled rice grain without any broken parts

Yellowing/discoloration - yellowing is caused by over-exposure of paddy to wet environmental conditions after harvest, and sometimes refered to as fermented grains. Yellowed grain

Bibliography and Links

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Economics

Economic Considerations

The section on economics highlights the economic considerations associated with farming in general and in a shift in technology in particular.

Introduction

- It is almost impossible to predict what the change in yield will be associated with any shift in management.
- Our strategy is to define the cost of the shift in terms of kg of grain.
- This allows an easily understood assessment of the risk involved in the technology shift.

Use the **Economic Calculator** to estimate the relative costs of practices in terms of the amount of harvested grain needed to pay for the different practices.

The discussion below shows a manual example of how costs are estimated in the **Economic Calculator**.

Calculating the economics of change - The information needed is:

- Cost of old practice (A)
- Cost of new practice (B)
- Farm grain price (C)

How much grain (kg) is required to break even with the new practice?

- = (B-A)/C
- Example for a shift in fertilizer rates
    - **Cost of old practice (A)**
        - Old practice = 50 kg N/ha as Urea
        - Amount of Urea required = 50 kg N/(0.46 N/kg Urea) = 109 kg Urea/ha (Approximately)
        - Unit cost of Urea (US$) = 0.20/kg
        - Cost of old practice = 109 kg Urea/ha * 0.20 $/kg = US$21.80/ha

Cost of new practice (B)

New practice = 75 kg N/ha as Urea; plus 20 kg P_2O_5 and 20 kg K_2O per ha

- Amount of complete fertilizer (14:14:14:) required to apply 20:20:20 ($N:P_2O_5:K_2O$) per ha = 20 (kg nutrient/ha)/0.14 (kg nutrient/kg product) = 143 kg product/ha (i.e., complete fertilizer)
- Unit cost of complete fertilizer = 0.17 $/kg
- Cost of complete fertilizer = 143 kg/ha * 0.17 $/kg = $24.3/ha
- Additional N required as Urea = 75 kg total N/ha required - 20 kg N/ha supplied as complete fertilizer = 55 kg N/ha required as Urea
- Amount of Urea required = 55 (kg N/ha)/0.46 (kg N/kg Urea) = 120 kg Urea/ha
- Unit cost of Urea (US$) = 0.20$/kg
- Cost of Urea = 120 kg Urea/ha * 0.20 $/kg Urea = US$24/ha
- Total cost of new practice/ha (B)
- Total cost = Cost of complete fertilizer + cost of Urea = $24.3/ha + $24/ha = $48.3/ha

- **Difference in cost of practices = New cost-old cost = $48.3 /ha - $21.8/ha = $26.5/ha**

How much grain is required to cover the costs of the new practice?

- Farm grain price (C) = US$0.24/kg
- Cost difference (B - A) = $48.3/ha - $21.8/ha = $26.5/ha
- Grain equivalent = 26.5 ($/ha)/0.24 ($/kg grain) = 110 kg grain/ha

Thus to cover the costs of the change in practice, the farmer must harvest at least an extra 110 kg Grain/ha.

Examples of Farm Costs

Comparative annual revenues and costs of rice production among RTDP farms, US $ hectare^{-1}, 1999.

	Central Luzon, Philippines	Central Plain, Thailand	Mekong Delta, Vietnam	West Java, Indonesia	Tamil Nadu, India	Red River Delta, Vietnam
				(US $ hectare^{-1})		
Gross Revenue	2083	1302	1160	1490	1375	1834
Labor	501	207	435	472	490	764
Hired	415	95	60	328	430	30
Family (imputed)	86	112	375	144	60	735
Fertilizer	139	125	95	73	90	145
Machine rental and fuel cost	109	147	40	44	70	3
Pesticides	47	91	44	65	7	45
Seeds	63	61	56	9	30	33
Other costs	29	4	12	7	11	78
Total costs per hectare	888	636	683	670	698	1068
Total costs per ton of paddy	96	59	74	69	62	86
				(costs as % of gross revenue per hectare)		
Labor	24	16	38	32	36	42
Fertilizer	7	6	5	3	4	7
Machine rental and fuel cost	5	7	2	2	3	0

Pesticides	2	4	2	3	0	2
Seeds	3	3	3	0	1	2
Other costs	1	0	1	0	1	4
All costs excl. land and mgmt.	43	49	59	45	51	58
				(% of total costs per hectare)		
Labor	56	33	64	70	70	72
Fertilizer	16	20	14	11	13	14
Machine rental and fuel cost	12	23	6	7	10	0
Pesticides	5	14	6	10	1	4
Seeds	7	10	8	1	4	3
Other costs	3	1	2	1	2	7

Note that all data are on an annual basis, not a per crop basis. For all sites, data are based on two crops of ric per year.

Source: Moya PF, Dawe D, Pabale D, Tiongco M, Chien NV, Devarajan S, Djatiharti A, Lai NX, Niyomvit L G, Wardana P (2001).
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Clean Seeds

The Changing Faces of Asian Rice Production

The objective of the following presentation is to highlight the key factors needed for the selection, production and preservation of high quality seeds. The presentation takes you through different stages of the process, touches upon useful technologies, and describes the impact of seed quality on rice crop yields.

The presentation has three sections:

1. Clean Seed
2. Post-production
3. Rice Quality

This presentation also includes a section on how to manage other factors in addition to seed quality which may influence the quality of rice. It clearly states "do's" and "don'ts" in each case, along with ideal conditions for optimum yields. Click **here** to begin the presentation and use the navigation arrows at the bottom of each slide to navigate the presentation's contents.

Prepared by: T Mew, M Bell, A Elepaño, R Raab
Design by: J.Gray-Donald, Shah Faisal

Technology Changes

Slide presentation

Click **here** to view a slide presentation concerning the Changing Face of Asian Rice Production. The slide presentation will load in a new window. When you have finished viewing the presentation, click the close box in the upper right corner of your screen to return to this window.

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