IRRI Training Module

Rice Storage

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IRRI

CGIAR Research Program on Rice
Global Rice Science Partnership

600 Year old Traditional German Warehouse

Rice Science for a Better World

Sources: W. Muehlbauer

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Harvesting

Threshing

Transport

Drying

Storage

Need

Rice grain

Problems

Farm level

Commercial

Technology

Managem.

Hermetic S

Pests

Milling

Packaging

Marketing

Rice Science for a Better World

Participants will learn about

- Need for storage
- Rice and interactions with the environment
- Present situation and problems
  - On farm storage
  - Commercial storage
- Best practice storage management
  - Technology
  - Management
- Hermetic storage

Rice Production in 2011

- World – 700 million tons
- Asia - 650 million tons
- Bag storage - 500 million tons

(Total world cereal and pulse production 2,300 million tons)

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Sources: FAO, USDA

Present Situation

Between 25-50% of the total grain value (quantity + quality) is lost between harvest and consumption in developing countries

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Quality loss

15-25% Physical loss

Postharvest Losses and Food Security

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"It is not so important to know whether the exact figures for postharvest losses are 15% or 25%. If we can just reduce them by just 5% we can make a huge difference."

Project partner from Vietnam during a joint field trip when asking about the magnitude of postharvest losses in Vietnam.

Rice production and milled rice export in 2008 in million t
(Source: World Rice Statistics)

	CAM	PHI	VTN
Annual paddy production	8.3	15.8	40.0
Milled rice production	5.4	10.3	26.0
5% loss equivalent	**0.3**	**0.5**	**1.3**
Net milled rice export	1.0	-1.5	7.0

Quantity Losses in Cambodia

(88 on farm studies)

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Post-harvest stage	Mean (%)	Range (%)
Cutting	**3.0**	**2.2 – 3.8**
Transportation	**3.6**	**2.0 – 5.2**
Threshing	**1.6**	**1.0 – 2.2**
Drying	**2.0**	**1.0 – 2.0**
Storage	**10.7**	**3.5 – 18.0**
Milling	**14.7**	**7.5 – 22.0**
TOTAL	**35.6**	**17.2 - 53.2**

Average Postharvest Losses in Southeast Asia

Physical losses in traditional postharvest chain

Cutting, handling
1-5%

Manual threshing
1-5%

Sun drying
3-5%

Open storage
5-10%

Village milling
20-30%

Small retailers

Quality losses resulting in 10-30% loss in value

Machine threshing
1-5%

Combine harvesting
1-5%

Mechanical drying
1-2%

Sealed storage
1-2%

Commercial milling
5-30%

Large retailers

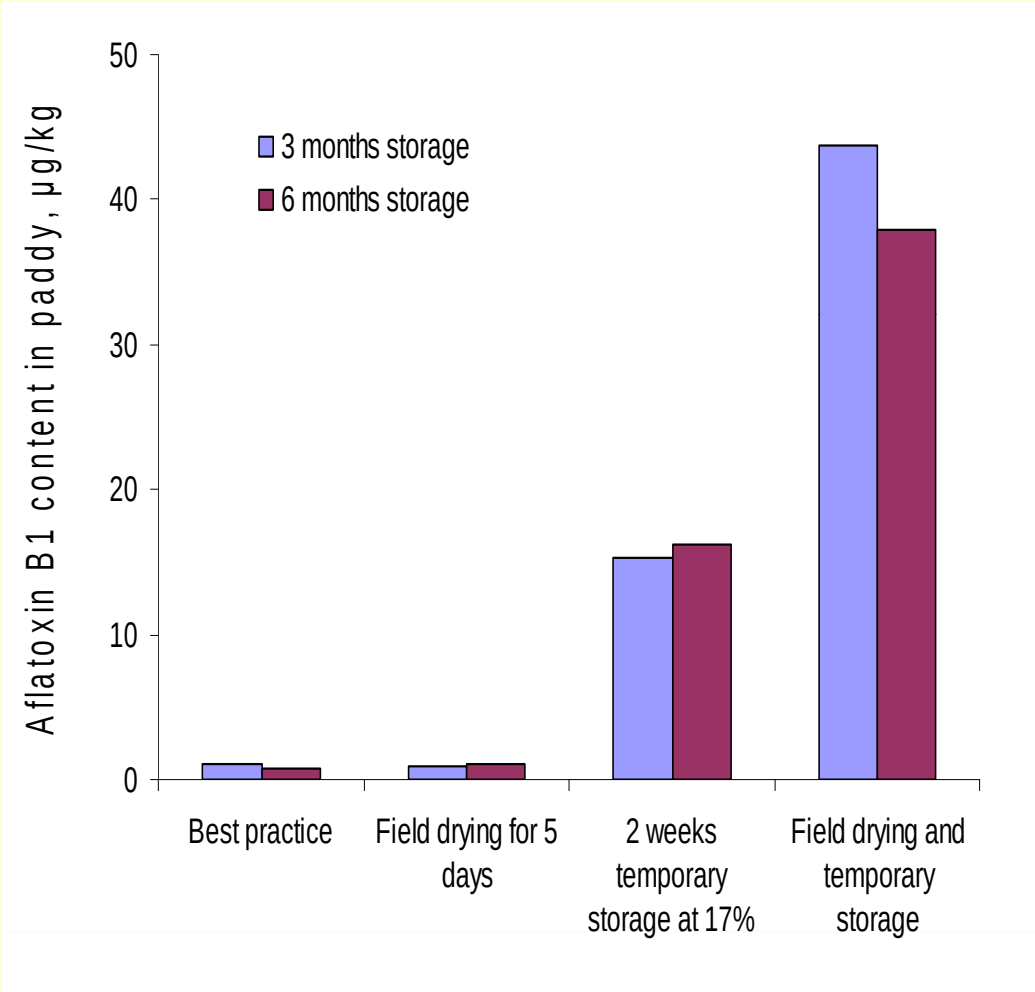
Physical losses in mechanized postharvest chain

Potential Mycotoxin Contamination in different PH systems

Simulated farmers practice compared to best practice postharvest management

Indications:
Aflatoxin might be a problem in smallholder postharvest operations

Ongoing follow-up:
Quantification in selected villages
Low-cost detection method
Other mycotoxins



Source: IRRI - C. Balingbing, 2008

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Rice Grains and their Interactions with the Environment

Rice Science for a Better World

Save Moisture Contents (MC) Depends on Purpose

- Harvesting
- Threshing
- Transport
- Drying
- **Storage**
  - Need
  - **Rice grain**
  - Problems
    - Farm level
    - Commercial
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MC	Purpose	Possible problems in storage	
> 14%	Unsafe, dry within 24h after harvesting	Rapid temperature increase, yellowing	Red
< 14%	Weeks to a few months of storage	Molds, respiration loss, insect damage, moisture adsorption	Green
< 13%	8 to 12 months storage	Insect damage	Green
< 12%	Farmers' seeds	Loss of seed viability	Yellow
< 9 %	Storage for more than 1 year	Loss of seed viability	Out of range

Equilibrium Moisture Content (EMC)

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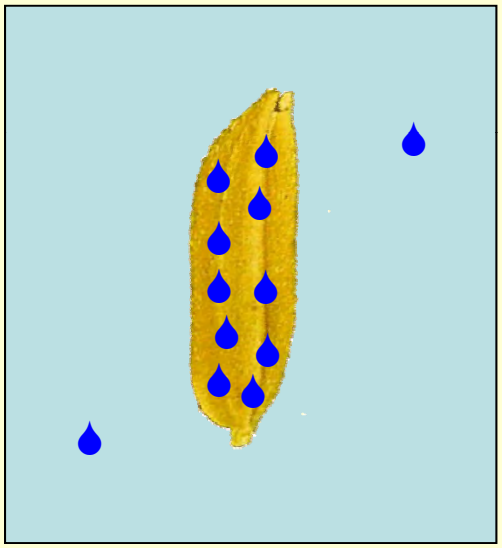
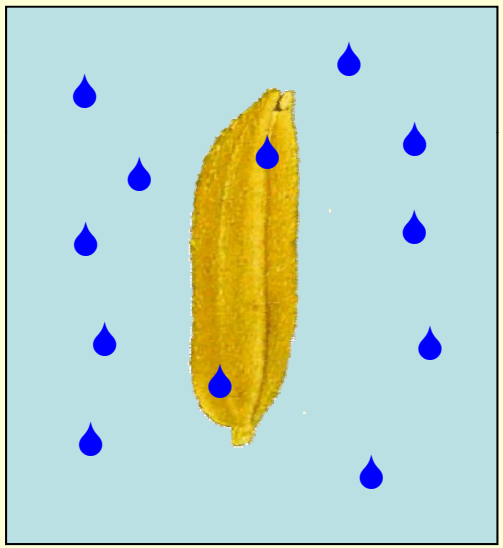
Paddy and rice are “hygroscopic”

Wet grain in dry air

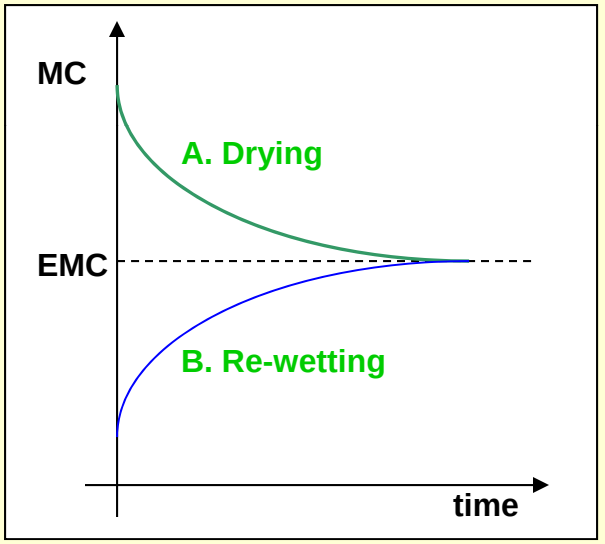


A. Drying

Dry grain in wet air



B. Re-wetting
Moisture adsorption



EMC is the moisture content the grain has after its water content has equilibrated with the water content of the surrounding air

EMC Table for Paddy

With color coding of IRRI Moisture Tester

	Relative Humidity	Storage Temperature, ºC						
	%	22	24	28	32	36	40	44
Save	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
Unsave	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

Final paddy MC in Percent

Equilibrium Moisture Content in Vietnam

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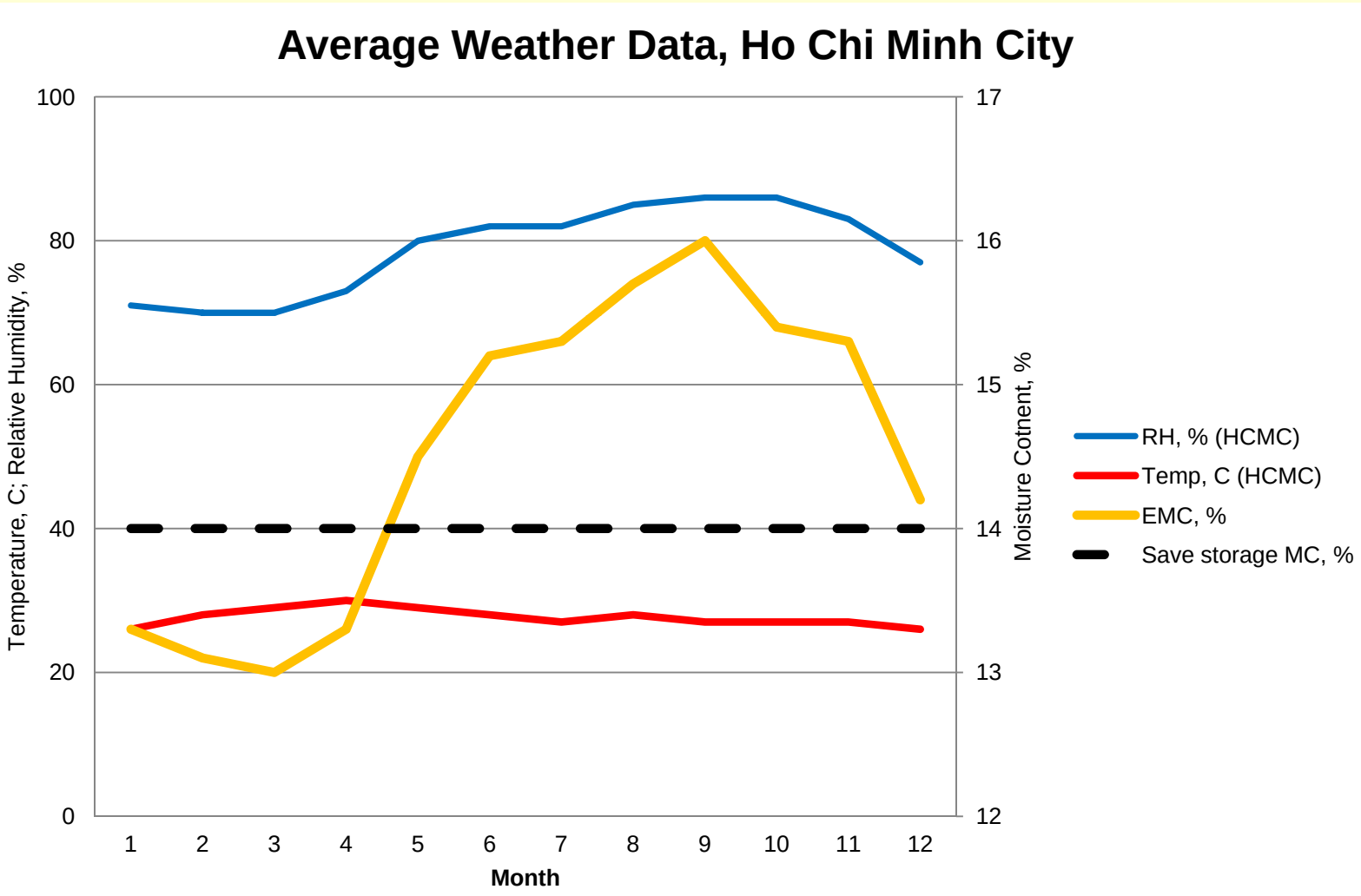

Source: http://www.saigon.climatemps.com/

Reasons for Post Harvest Losses

1. Poor product coming into storage (improper harvesting and drying)
2. Poor storage management
3. Poor quality paddy + poor milling techniques

Present On-farm Storage Situation and Problems in Asia

Traditional Bag Storage
(Indonesia)

Harvesting

Threshing

Transport

Drying

Storage
- Need
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Granaries

(Cambodia, Myanmar, Lao, Indonesia)

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Woven Bamboo Basket

(Cambodia and Myanmar)

Other Farm Level Storage Systems

Harvesting

Threshing

Transport

Drying

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Clay pots (Bangladesh)

Wooden containers

Steel drums

Bulk storage at home (Lao PDR)

Concrete Bin

(Bhutan)

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Household Steel Silos

Source: FAO, 2008

Bhutan

- Protects from rodents, birds
- Expensive
- Does not control insects
- Although some information materials say the silos are hermetic, this is NOT hermetic storage

Summarizing Existing On-farm Storage Situation

- Grain is stored in open systems in bags or open granaries
- Grain is exposed to insect, rodent and bird attacks
- High equilibrium moisture content >14.0 under tropical conditions
- Grain is not always protected from rain

Farmers Present Storage Practices

1. Sell excess immediately after harvest (indebted or poor storage)
2. Take grain out and re-dry during storage period
3. Store seed in “sealed” containers

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Present Commercial Storage Situation and Problems in Asia

Commercial Bag Storage Systems

Harvesting

Threshing

Transport

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- Open to atmosphere
  - moisture uptake,
  - pest problems
- Store in batches
- Often no headways and walkways
- Relatively easy to fumigate

Commercial Bulk Storage: Warehouse

- Flexible, can be used for other purposes
- 500-10,000 tons
- Divisions can separate for different sizes
- Aeration facilities available
- Automation difficult, labor intensive
- Cheaper than silos
- Control of rodents, birds and insects is very difficult

Front loader tractor

Telescopic loader

Commercial Bulk Storage: Indoor Silos

- Not common in Asia
- Automatic loading and unloading using conveyors
- Compartments for different varieties / lots
- High investment per ton

Large container with hopper bottom

Small scale container

Commercial Bulk Storage: Outdoor Silos

- Not popular in Asia, but new installations
- Management problems -> Condensation
- Efficient use of space
- Automatic loading, unloading
- Aeration
- Easy to control pests, sealed for fumigation
- Less problems with rodents and birds

Concrete and steel silos

Silo Complex in Vietnam

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Best Practice Storage Management

Pre-condition: Proper Drying

- Dry immediately after harvest to safe moisture content (with 24 hours to 14% moisture or less)
- Avoid any re-wetting of dried grains
- Avoid mixing grains of different lots with different MC.

Example Vietnam

Storage assessment in 2012

Facility	Process	Head rice recovery
1	Paddy purchasing	53%
2	Reverse processing	**43%**
3	Reverse processing	**47%**

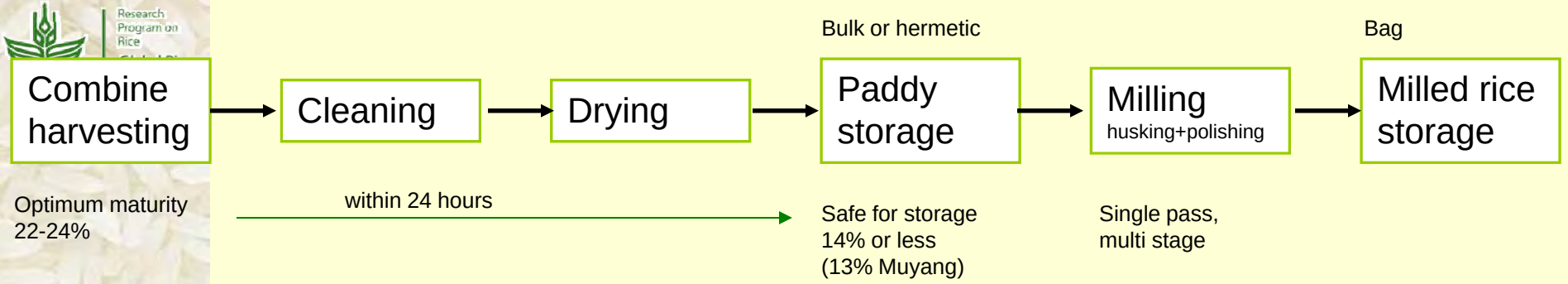
- Visit to three representative processors

1. Saigon – “Satake” Food enterprise, HCMC **(indoor silo for paddy storage)**
2. Song Thuan Rice Mill **(indoor silo for brown rice / milled rice storage)**
3. Tra Noc (outdoor) **Silo** Complex at Song-Hau Food Company, Can Tho City

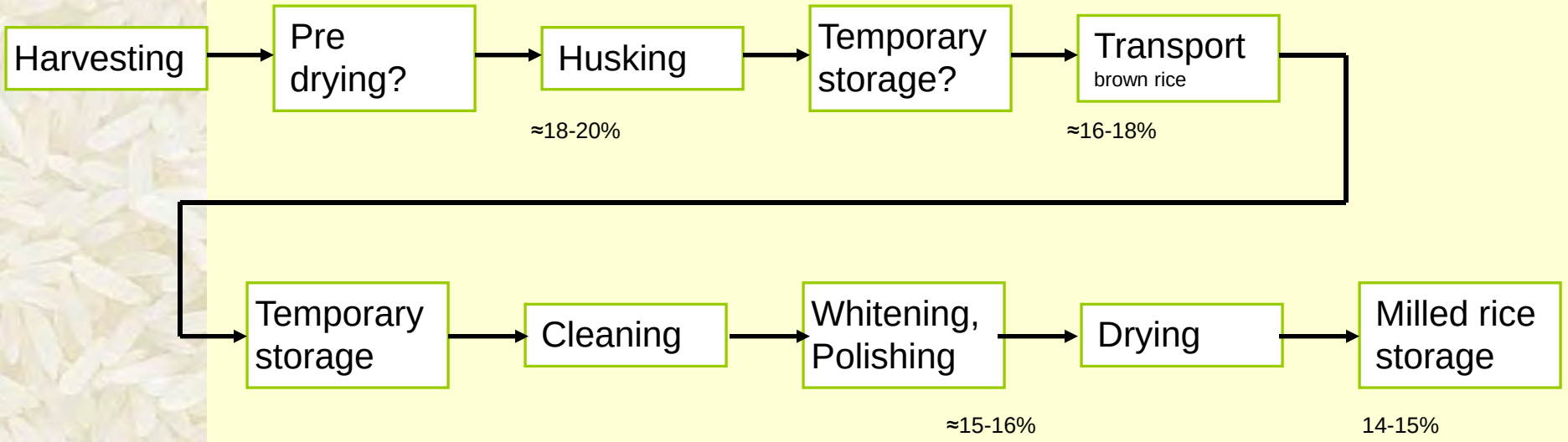
- Results

– Small sample size, not conclusive
– Only # 1 currently stores paddy, produced high quality milled rice
– High moisture content, all store at 15% or higher
-> yellowing, shifting to other silos to extend storage time
– High percentage of impurities: 4-5%
After cleaning still 1-2%
– Many varieties in rice production
– Investment by the private sector is happening
– Limited know-how on best practice and technology options
– High cost of credit for commercial operation (not for food security)
– Very little quantification / measurements

Best practice according to IRRI for minimal loss and optimum quality



Current Situation in Vietnam with “reverse processing” or “re-processing”



What is required of a good storage system

- Prevention of moisture re-entering the grain after drying
- Protection from insects, rodents and birds
- Ease of loading and unloading.
- Efficient use of space
- Ease of maintenance and management.

Granary Improvements

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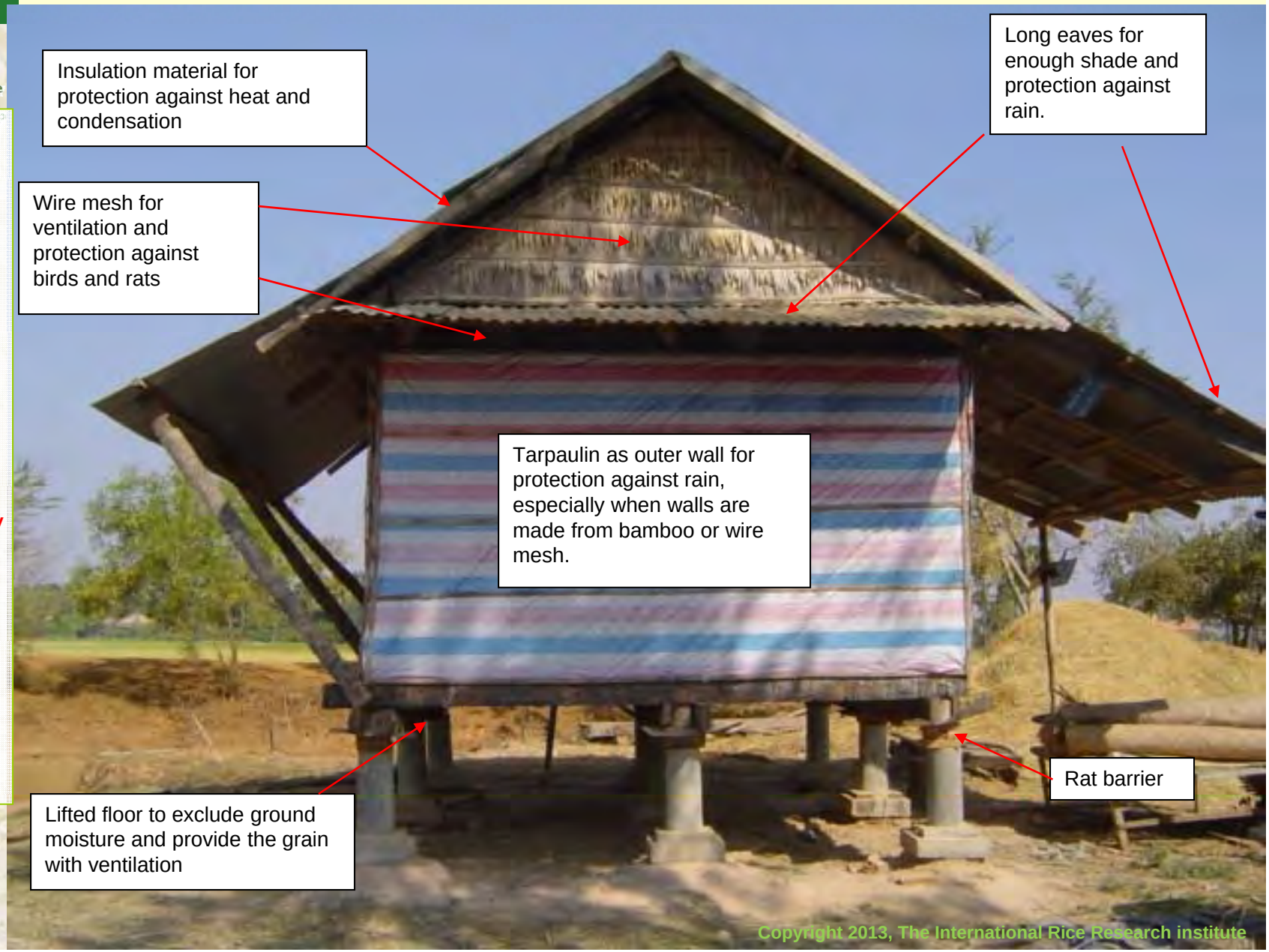

Open Storage: Storage Hygiene

- Keep storage areas clean.
- Clean storage rooms after they are emptied
- Placing rat-traps and barriers in drying and storage areas. Cats deter and help control rats and mice
- Inspect storage room regularly to keep it vermin proof.
- Inspect the stored seeds once a week for signs of insect infestation.

Silo Storage

- Uniform drying and cleaning of the paddy
- Buy the silo as a system (silo, conveyors for loading and unloading, aeration equipment…)
- Level the top
- Use a roof exhaust (humidity controlled)
- Use aeration as recommended
- Cleaning and sanitation between uses

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Pest Control

See separate presentation

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Hermetic Storage

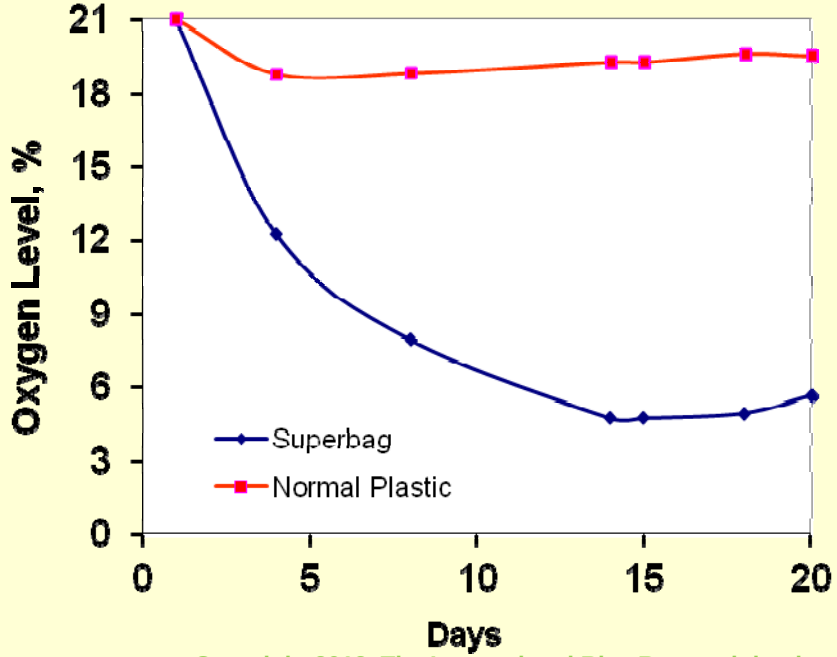
Hermetic Sealed Storage Systems

5 t Cocoon

50 kg “Super bag”

Principle

- Special plastic - low oxygen permeability
- Biological activity reduces oxygen level quickly
- Insects die at low oxygen level
- Plastic prevents moisture adsorption



What Consumes the Oxygen?

- **Insect infestation**
- Microorganisms, especially in wet rice
- Oxidation and lipases of the oil in the rice bran
- Seed respiration, but little because dry seed does not respire much

What happens at low O_2, high CO_2 Atmosphere?

- O2 < 3% is lethal to insects at all stages of development
- At higher O2 levels insect activity gets reduced and even if they are not killed, the don't multiply

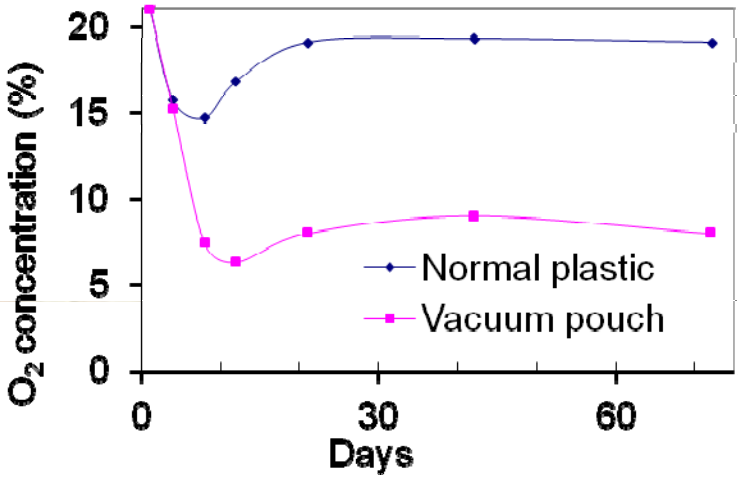
Hermetic Storage: Research Findings

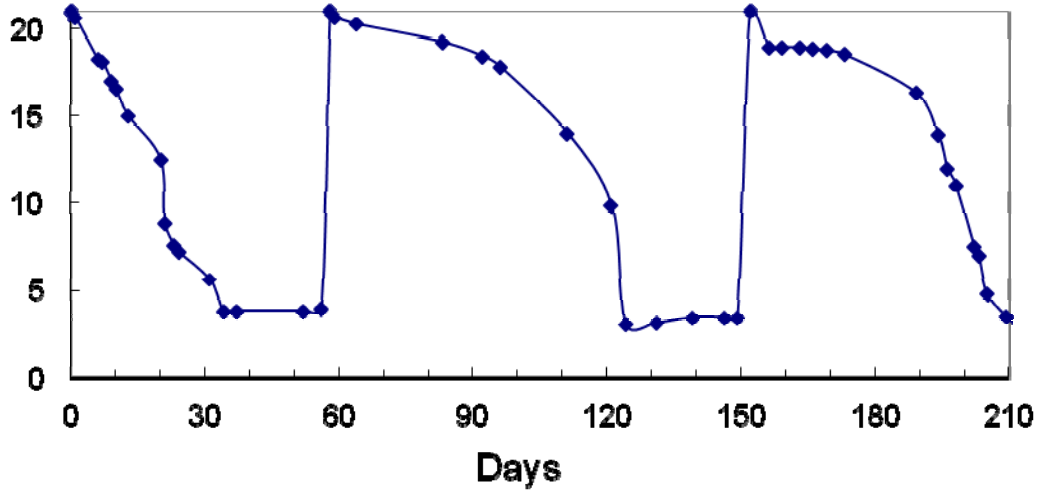
- Works for 3kg – 50 ton Cubes
- Controls insects without pesticides
- Maintains grain moisture content
- Approximately doubles the life of seeds
- Maintains milling quality
- Protects grain from rodents and some birds

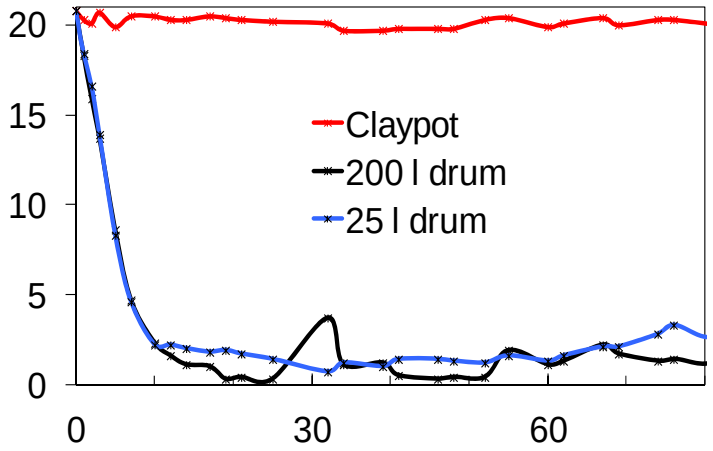
Parameters Evaluated

1. In store atmosphere (02)
2. Grain moisture content
3. Seed germination
4. Insects
5. Grain quality
6. Farmer uptake

Intergranular Atmosphere







Findings:

1. Normal plastic is not hermetic
2. Don't open!
3. Insect population increases over time, but is controlled by the system

Maintains Moisture Content

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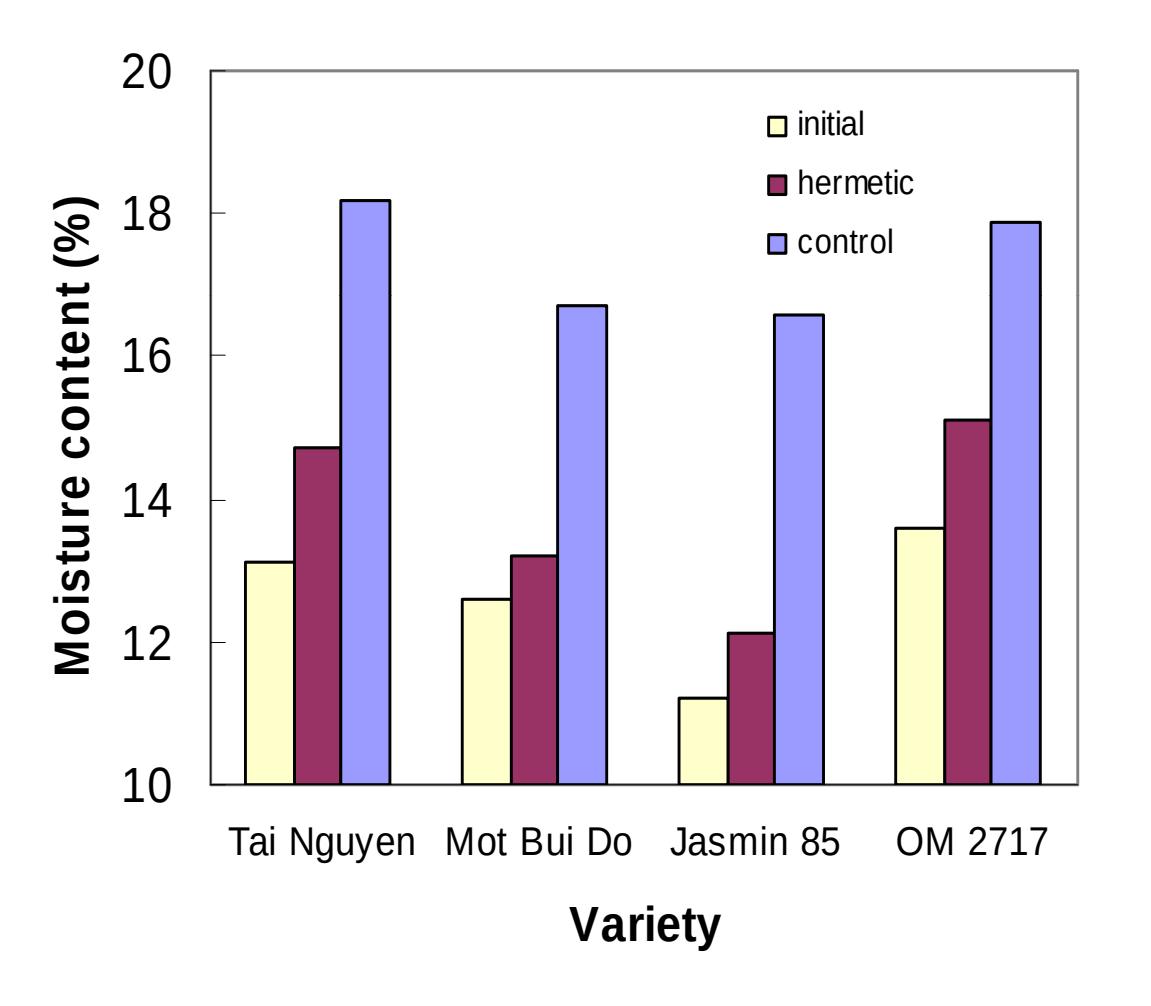
- 8 months of storage
- 4 varieties
- Hermetic: IRRI super bags
- Control: Woven PVC bags



Data from 2005, Bac Lieu Seed Center, Vietnam

Provides Insect Control

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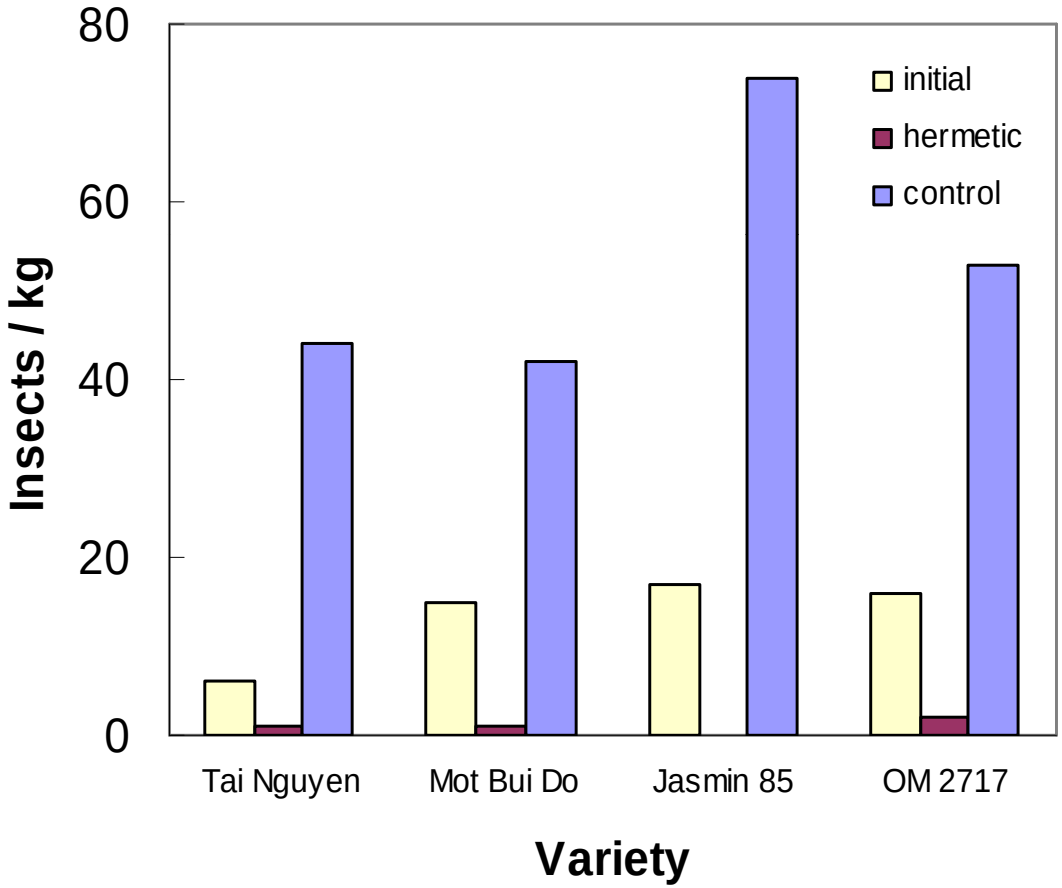

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Maintains Germination

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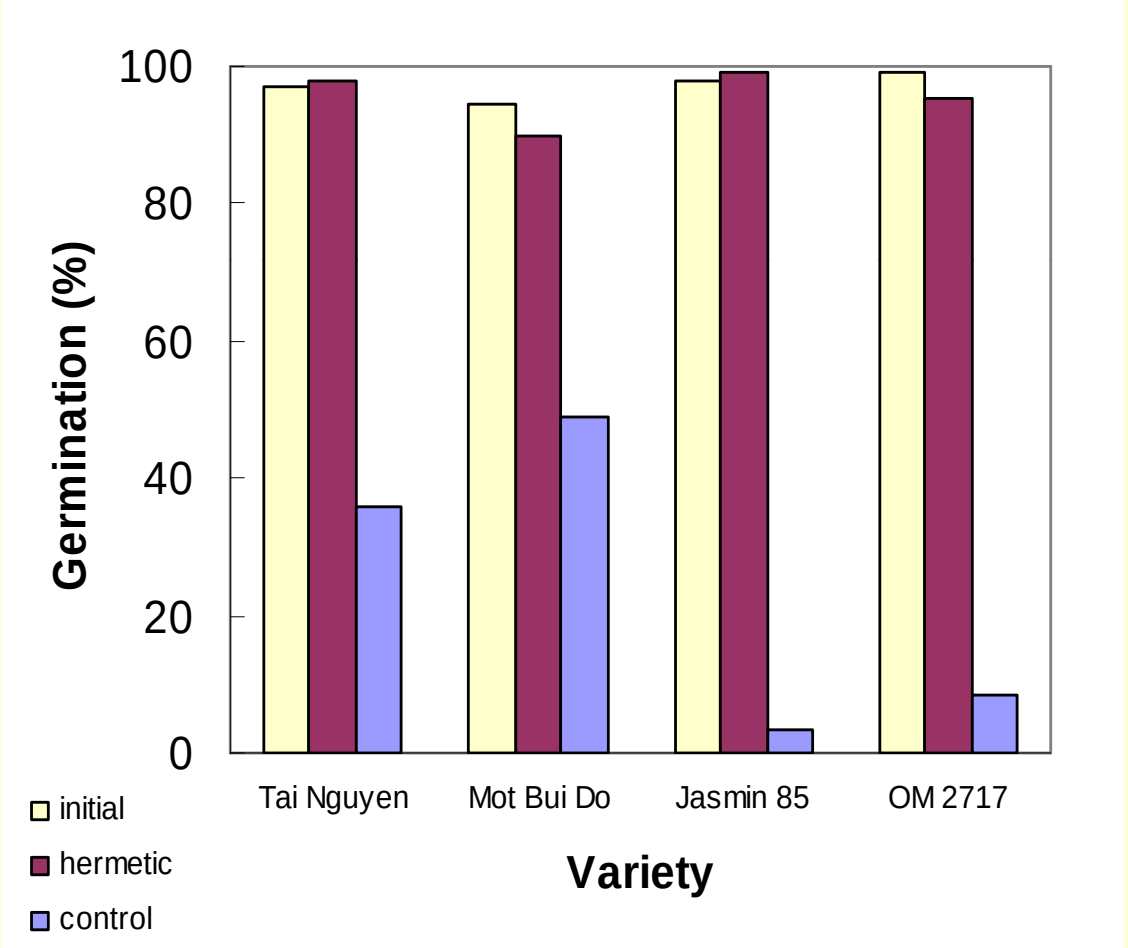

Data from 2005, Bac Lieu Seed Center, Vietnam

Higher Returns in Milling

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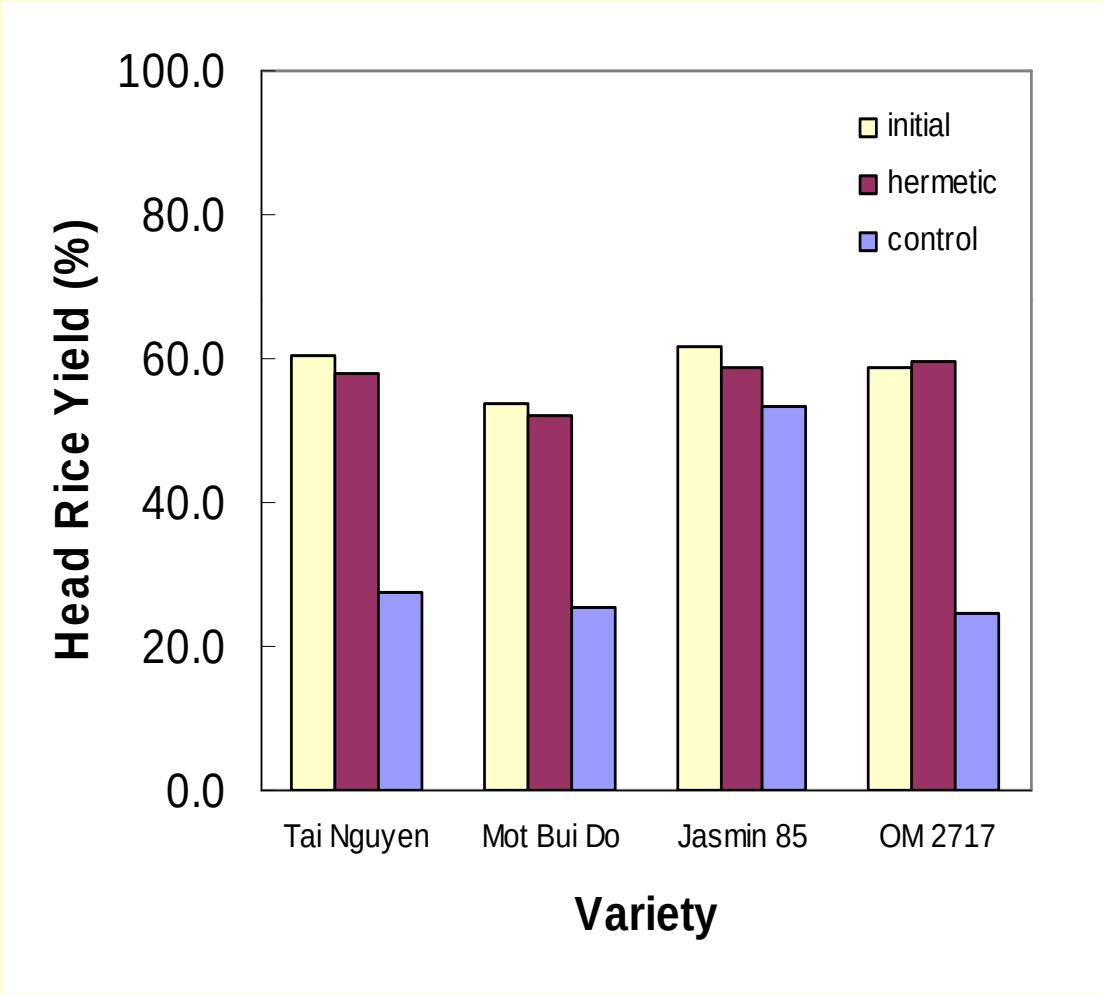
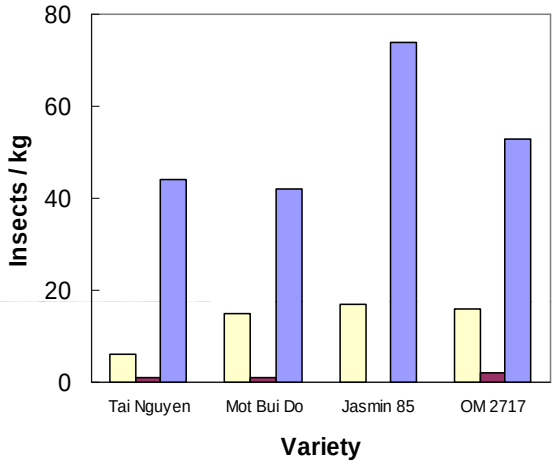


Data from 2005, Bac Lieu Seed Center, Vietnam

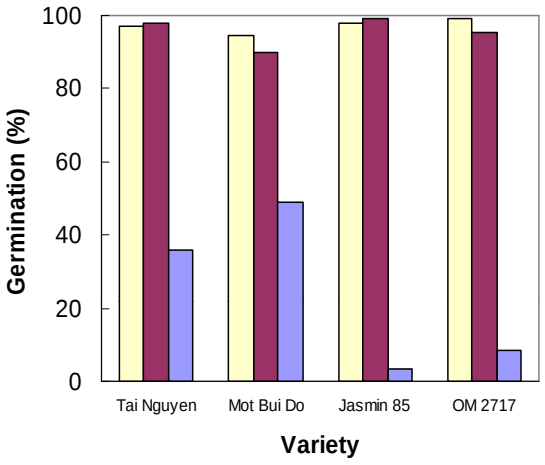
Benefits of Hermetic Storage

Insect control



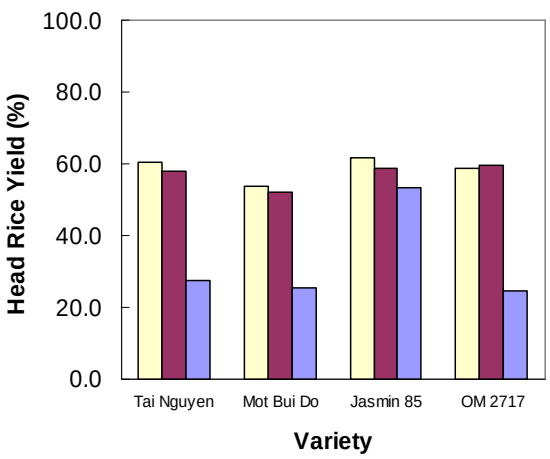
No pesticides / fumigation (farmers often store inside the house to avoid theft)

High germination rates



Farmers in SE Asia use around 80% own seeds and use high seed rates to compensate for low germination -> **more grains to sell**

Higher milling returns



More grain to sell
Also controls moisture content -> protection from mycotoxins

Initial sample | After 8 months hermetic storage | After 8 months traditional storage

Source: IRRI - Bac Lieu Seed Center, Vietnam collaboration
Eight months of storage, 4 varieties, comparing IRRI Super bag with farmers practice

Works with other crops

Photo: CIMMYT

Technical Evaluation of Hermetic Storage

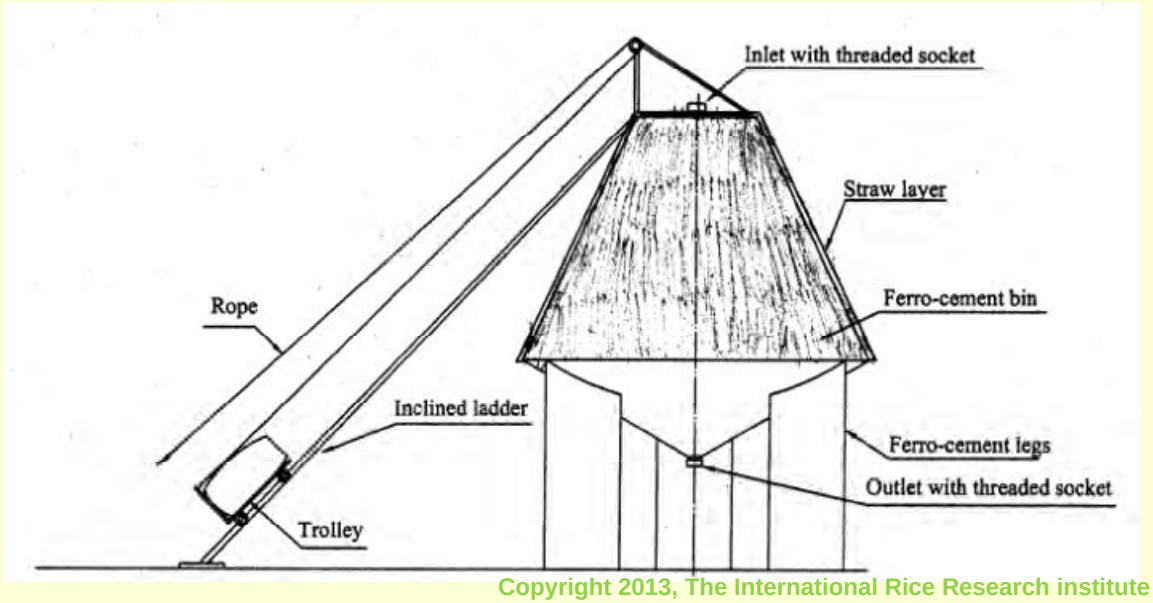
- Through Irrigated Rice Research Consortium Partners in Vietnam, Philippines, Indonesia, Cambodia, Myanmar, Lao PDR, Thailand from 2004 to 2012
- In collaboration with research partners and by other partners also in Sri Lanka, India, Bangladesh
- Technically feasible

Hermetic storage options

Transfer a principle..

Locally available containers

Ferro cement bin in Sri Lanka



- Capacity: 50kg
- Cost: US$ 1-5
- Generation 1: Sealing by twisting
- Generation 2: Sealing by zip lock

Rice Science for a Better World

Super Grain Bag, High Capacity (SGB-HC), for use with Big Bag

See larger image: plastic bags/sacks/PP big bag/jumbo bag/bulk sack

- Capacity: 1t
- Cost: US$ 58
- Storage in bulk,
- Disadvantage: Not UV stabilized, thin material (like Super bag)

GrainSafe II and GrainSafe III

- Capacity: 1t
- Cost: US$ 175 (II), US$ 150 (III)
- Storage in bulk (Grainsafe II) or in sacks (GrainSafe III)
- GrainSafe II: Sprout on bottom to take grain out without disturbing the atmosphere

Underneath the GrainSafe showing the tied downspout. Loosen the tie to start discharge of grains.

Cocoon

Section 1A -- Organic GrainPro Cocoo			
GPC-005	5 Tonne*	$	1,250.00
GPC-010	10 Tonne*	$	1,500.00
GPC-020	20 Tonne*	$	2,500.00
GPC-2-050	50 Tonne*	$	4,650.00
GPC-3-050	50 Tonne*	$	4,450.00
GPC-100	100 Tonne*	$	8,050.00
GPC-150	150 Tonne*	$	9,200.00
GPC-300	300 Tonne*	$	14,000.00

Tasks: Storage activities

- Determine density of paddy, husk, milled rice, bran
- Evaluate seed storage systems at IRRI
- Load and sealing 5 t hermetic storage system (2 groups)
- Make small seed storage system (1 per group)
- Sample seed store and set up germination test
- Sample stored grain and identify insects
- Seal grain storage system ready for fumigation

Evaluating a seed store

	Store 1	Store 2	Store 3
Grain Protection			
Moisture content			
Insects			
Rodents			
Birds			
In store Hygiene			
Storage above floor (pallets)			
Clearways (0.5m)			
Batch storing			
Clean			
Management strategies			
Store cleaning after season			
Bags cleaned, dipped			
Fumigation options			

Paddy under MA conditions:

- No change in MC
- No weight loss/increase
- Infestation controlled due to low O2/high CO2 (<3% O2 is lethal to all stages of insect development)
- Molds are controlled
- Better head rice/ less broken

Milled rice

- No infestation
- No weight loss
- Storage up to one year
- No change in physical appearan
- Fragrance/aroma retained
- If no MA build up within a short time (4 weeks) plastic liner is at risk due to activity of lesser grain borer (*rhyzoperta dominica*)

Source: GrainPro

Brice (brown rice)

- Marketing is a problem due to short shelve life
- Enzymatic lipases which starts after the husk is removed, causes a rancid taste in the oil of the bran layer
- Lipases combined with infestation will cause a rapid modified atmosphere enabling long term storage
- MC will be stable

Source: GrainPro

Rice Bran

- Valuable additive for feedmills due to high oil and protein content
- Used for rice oil extraction (leftover is pelletized and sold to feedmills)
- Cannot be stored for more than a few days due to infestation and rancidity

Source: GrainPro

Storage of (hybrid) seeds

- Seeds stored in regular warehouses will deteriorate in 3-6 months
- MA storage replaces successfully cold and air conditioned stores
- Acceptable germination rates are kept for one year or more
- Seeds can be stored outdoor
- Seeds are without insect damage

Source: GrainPro

Hermetic Super Bag Storage, Sulawesi

Village/ Treatment	Germination, %		Moisture content, %		Insect count/100g	
Awolagading	Initial	Final	Initial	Final	Initial	Final
IRRI Super Bag	95.6	91.2**	11.9	13.5**	7.2**	0.8**
Ordinary plastic sack	91.2	14	12	16.6	12	23
LSD (0.05)	4.66	1.84	0.27	0.33	2.22	4.05
Ujung Tanah	Initial	Final	Initial	Final	Initial	Final
IRRI Super Bag	90.8	88.2	11.9	14	8	1
Ordinary plastic sack	86.6	30.8	12.4	16.5	11	21.8
LSD	4.81	8.25	0.95	0.68	3.76	4.05

Source: IRRI ACIAR/SMAR project

n = 5 farmers in each village

LSD = least significant difference.

** Means are significantly different at 5% level of significance (P<0.05).

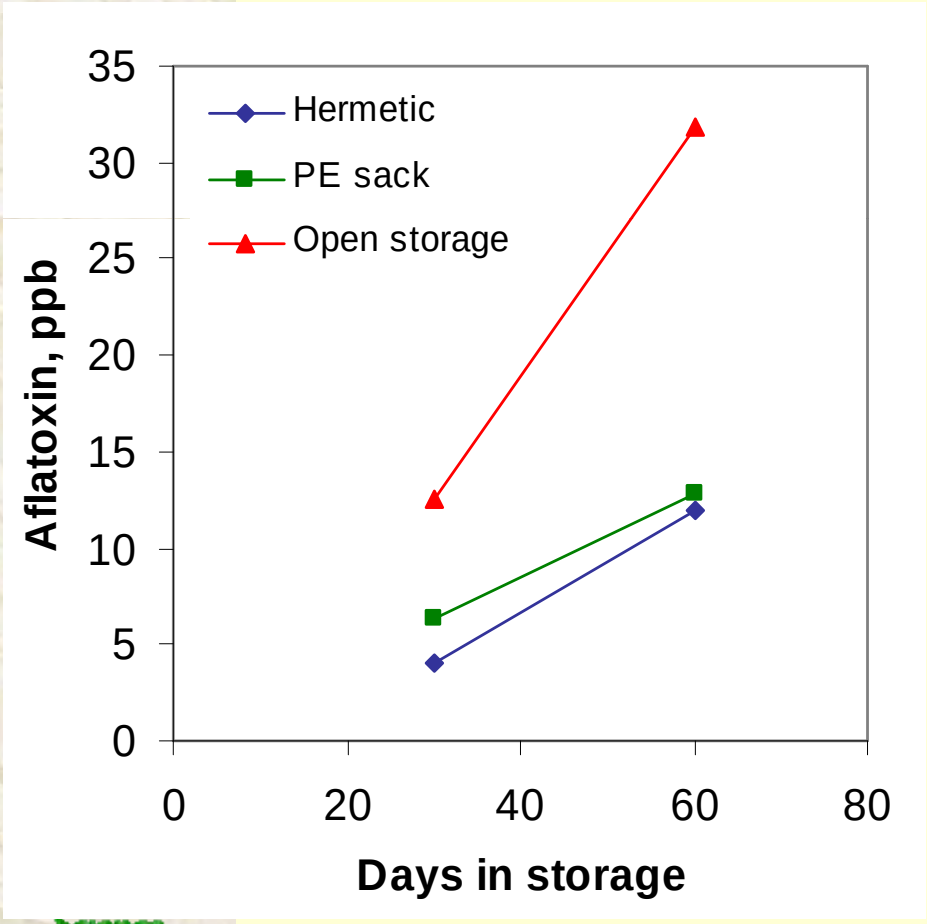
Case study example: Super bag trials by Romeo Junasa (farmer)

- End-user type: Farmer
- Stored seeds, 3 mos (May-July)
- Stored 40kg in SuperBag and 80kg in 2 Polypropylene bags
- Business model: Grows rice 2 seasons/yr, on 1-ha area, buys 120kg seeds per season and stores them until needed (3 months usually).

Economic Calculation, Super bags, Philippines

Current practice: (PP bag):	
Amount of seed currently used by end-user per season	120 kgs
Germination rate of seed with current practice	60-70%
Seed rate	120 kg/ha
No. of seasons in a year paddy is grown	2
Seed stored in Super bags	
Germination rate (GR)	Close to 100%
New seed rate given this GR (better than current practice)	40 kg/ha
Amount of seed saved	80 kg
Market price of seeds	P1200/40kg
Total additional profit	P2400
Cost per season (Cost of Super bag X No. of Super bags)	P100 X 1 bag
Additional net profit per season	**P2300 (55USD)**
Additional net profit if SB is used for 2 seasons	**P4600 (110USD)**

Outlook: Brown rice storage



- Brown rice has a very short shelf life
- Aflatoxin and FFA development is a problem
- Initial results indicate that the Super bag can slow down aflatoxin development
- (minimum detection level: 4ppb)