Seed Storage and Pest Management

Small -Scale Seed Production and Utilization

Tropical Ag Development Course 2019

ECHO Inc.

A development worker once said, “I always seem to be six months away from losing my seeds.”

Have you ever stored seeds?

Were the seeds suitable for planting or eating afterwards?

Would anyone like to share an experience?

Goals for this session

- Learn how seed quality, over time, is affected by storage conditions including temperature, moisture, and pests.
- Learn principles and context-appropriate practices and technologies for controlling seed loss factors and pests.

Assumptions—in terms of flow of operations

- Seed has been multiplied and collected
- Pests were managed as well as possible in the field
- Seeds have been cleaned and are being dried in prep for storage

Assumptions—in terms of content for this session

- Much of the content addresses storage of small quantities of seed for planting.
- We will also discuss storage of larger quantities for consumption or planting on a larger field scale.

FACTORS AFFECTING SEED LOSS

Learning goal: be able to explain the impact on seed life, over time, of environmental factors including temperature, humidity and pests

Seed Type

Orthodox seeds	Recalcitrant seeds
Can be described as “desiccation tolerant”, as they can be dried to low moisture content (e.g., 10% or less)	Can be described as “desiccation sensitive” as they do not tolerate drying well
Can usually be stored under freezing conditions	Intolerant of freezing temperatures
Can usually be stored for a year or more, although there are short-lived orthodox seeds.	Must be planted soon after harvesting
Tend to be small in size	Tend to be large in size

Remainder of this session focused on orthodox seeds

Remember- seeds are alive

- Orthodox seeds enter a resting state prior to germination.

- In storing seeds, we want to slow down metabolic processes (respiration) for longer storage life
  - *Keep food reserves from being used up*
  - *Prevent mold or premature germination*

- We also need to protect seeds from pests

Harrington's rule regarding:

Two primary storage factors

- Moisture Content/Humidity
  - *For every one percent increase in seed moisture content, seed storage life is reduced by half (applicable from 5 -14% seed moisture).*

- Temperature
  - *For every five degree Celsius increase in temperature, seed storage life is reduced by half (applicable from 0 -49 degrees Celsius)*

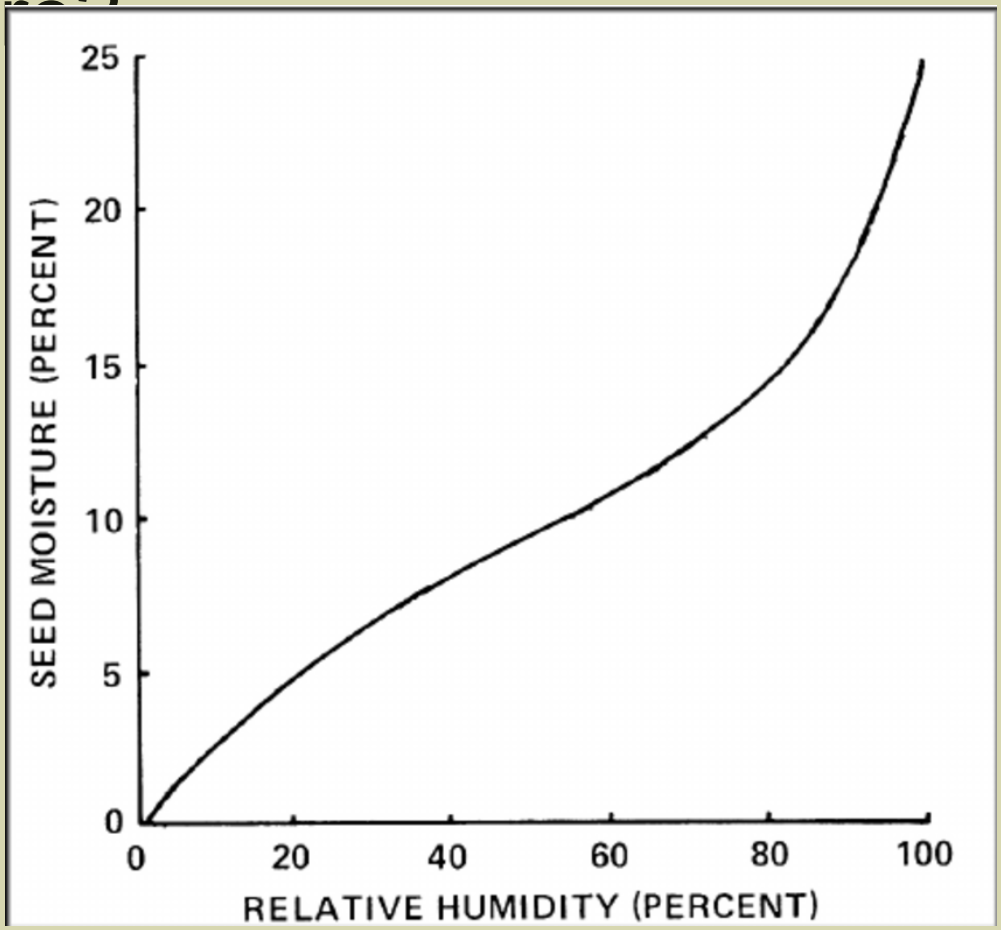
Harrington, J.F. (1960). Thumb rubs of drying seed. Crops & soils 13, 16-17

Chin, H.F. 1989. Storage and testing of forage seeds in the tropics. Pp. 151-156.

What is the right seed moisture content for storage?

- High end:
  - *Maximum seed moisture content above which fungal mold develops*
    - 12% for oily seeds such as cotton and soybeans
    - 14% for starchy seeds such as maize and wheat
  - *Rapid deterioration at 18% to 20% moisture*
  - *Germination of non -dormant seeds occurs at 30% moisture*
- Low end: in an ECHO research trial, sorghum seeds were killed with seed moisture content below 4%
- Ideal moisture content for storing seeds
  - *For storing 10 -20 years (pg 91 of Manual of Seed Handling, Bioversity)*
    - 3% to 8% for seeds that have poor storage traits (oily seeds; onion)
    - 7% to 11% for seeds with good storage traits such as grains
  - *At ECHO seed banks with inventory cycling every 1 to 5 years:*
    - < 10% ideal
    - <12% more realistic in low-resource settings in the tropics

Relationship between relative humidity of the surrounding air and seed moisture?



Justice and Bass, 1978

Example from ECHO research

Moisture and germination of okra seeds kept in outdoor ambient conditions under screen porch (humidity around 90%)

Seed moisture (%)

Seed germination (%)

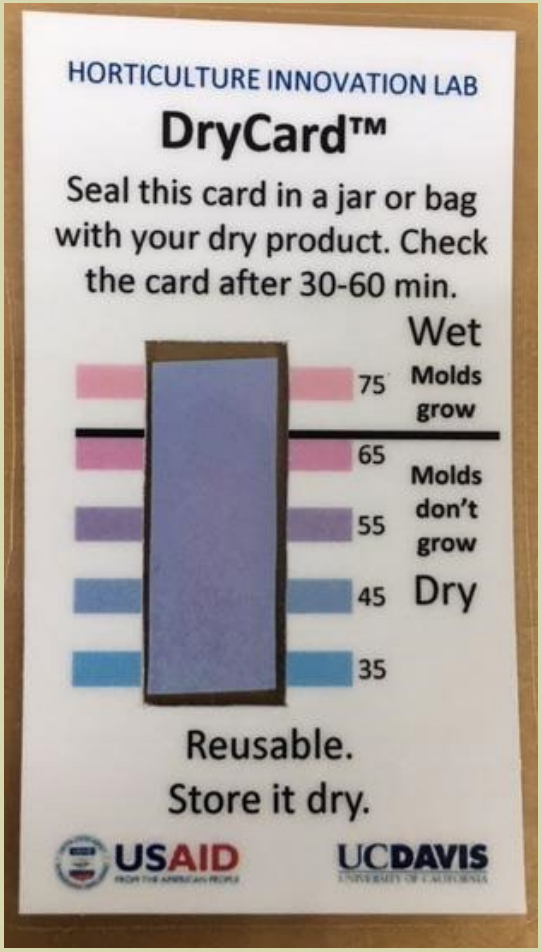
Proper Temperature and Humidity

- Rule of thumb: Temp (°F) + % humidity ≤ 100

- For long term storage of seeds, humidity is a more important factor than temperature. High humidity & seed moisture reduces storage life through:
  - *Heat buildup*
  - *Premature germination*
  - *Fungal rot (an issue at or above 65% relative humidity)*

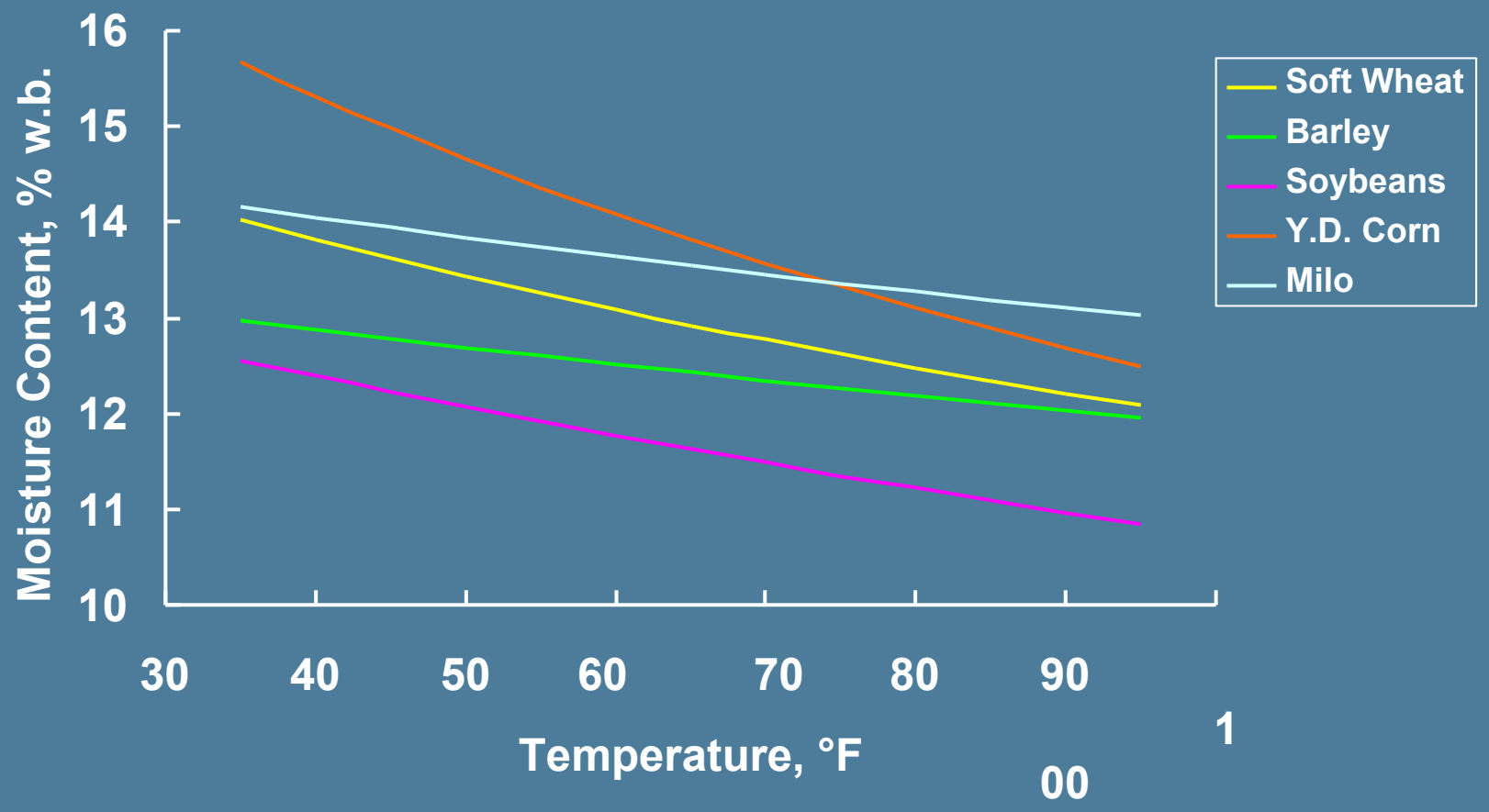
Which seed is moldy?

Dry card with moldy maize

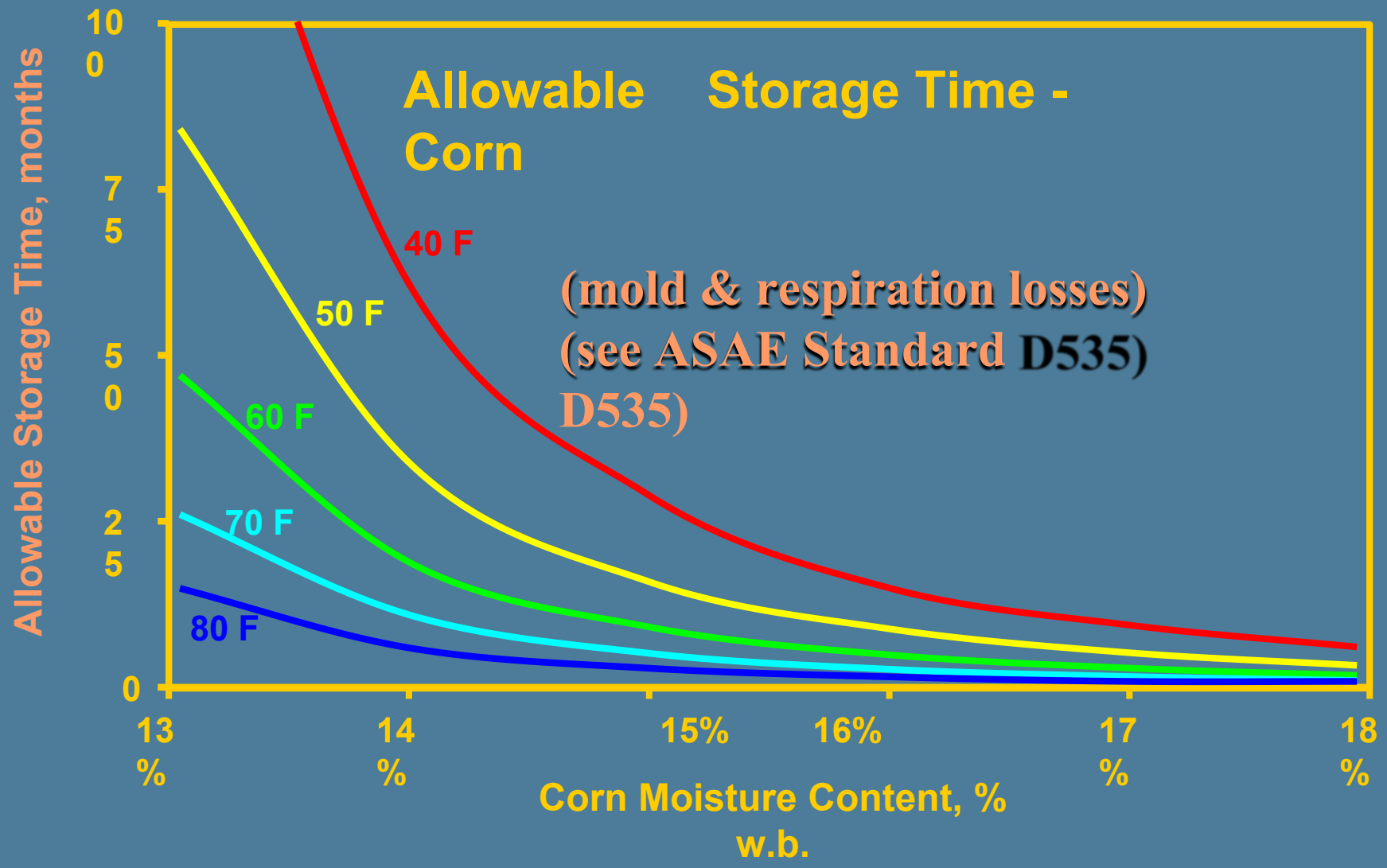


Mold Control in Stored Grain

- Approximate safe storage moisture content



Grain Moisture and Molds



Are my seeds dry enough to store?

- Most precise/accurate methods
  - *Oven-dry method*
  - *Various meters available*

- Rough indicators
  - *Dry cards and humidicator strips*
  - *Salt-jar test*
  - *Bite/bend tests*

Oven-dry method

- Obtain weight of fresh seeds
- Grind seeds into smaller particles (if required)
- Obtain weight of dry seeds after drying
  - *at 103 for 17 hours for oily seeds*
  - *at 130 for 1 -4 hours hour for non -oily seeds.*

$$\% \text{ moisture content} = \frac{\text{weight of fresh seeds - weight of dry seeds}}{\text{weight of fresh seeds}} \times 100$$

For more details, see page 30 of: Rao NK et al. 2006. Manual of Seed Handling in Genebanks. Handbooks for Genebanks No. 8. Bioversity International, Rome, Italy.

Moisture meters

- Depending on the meter, they work based on
  - *Oven-dry concept*
  - *Electrical devices that operate based on:*
    - Capacitance—electricity passed through seeds of known weight; moisture related to “dielectric constant”
    - Resistance---seeds conduct more electricity as moisture content increases

- Calibration: some meters are designed for specific crops

- Sample size: amount of sample, and whether or not the sample is destroyed, varies between meters

Dry cards/humidity strips

- Place a humidity sensor or "Humidicator paper test strip" where seeds are being dried

- Seed moisture will equilibrate with humidity in the container. NOTE: at the same humidity, seeds high in oil will be dryer than those high in starch.

- Consult tables in literature to approximate seed moisture content at a given level of humidity

  – *Table 4.4 (page 39) in Rao NK et al. 2006. Manual of Seed Handling in Genebanks. Handbooks for Genebanks No. 8 . Bioversity International, Rome, Italy.*

  – *Click on "Moisture Content Calculator " on Rhino Research Group (focused on Zeolite drying beads) web page*

Rough indicator tests

- Bite/fingernail test for beans: if a mark is not left on the seed, it is most likely dry enough for storage.

- Bend test for cucurbits: dry seeds should not bend easily

- Salt jar test- based on the fact that salt clumps at relative humidity levels of 70-75% (Sutcliffe and Adams. 2014. Low-cost monitors of seed moisture status. Royal Botanic Gardens, Kew)
  - *Place seeds in a dry bottle or jar*
  - *Add at least a teaspoon (pg 364 of FAO doc), or up to half the volume of the jar (Sutcliffe and Adams)*
  - *Close the lid and mix/shake the seeds and salt in the jar*
  - *If seeds are dry, the salt settles to bottom of the jar; if seeds are too wet to store, the salt sticks to the sides of the jar.*

Salt jar test--example

Dry maize: salt settled at the
bottom of the jar

Wet maize: salt stuck to the
sides of the jar

Seed Moisture Testing & Monitoring Activities

- Test seed moisture content with moisture meters
- See technologies for monitoring temperature and humidity

CONTROLLING SEED LOSS FACTORS

Learning goal: Identify context-appropriate practices/technologies for managing the seed storage environment---to keep quality, pest-free seeds.

Seed storage facilities--range from:

- State of the art technologies:
  - *Walk -in coolers*
  - *Dehumidifiers*
- Mid-range technology such as:
  - *Modified shipping containers*
  - *Coolbot and dehumidifiers*
- Low-cost technologies
  - *Earthbag structures*
  - *Traditional homes with seeds kept over cooking fires*
- Household level to community seed banks

State of the art

www.seedsaversexchange.org

Traditional methods—Where have you seen people store their seeds?

Many people around the world store their seeds above the fire/cook place:

- *low humidity*
- *smoke drives away insects*

Seed Storage: Seed shelf (Cambodia)

Seed Storage: Seed shelf (Malawi)

Low-cost earthbag house

Seed Storage Facilities Activity

- Tour seed barn area to see various storage structure options

- Learn ways in which temperature and/or humidity are controlled in
  - *an entire room*
  - *in containers within a room*

- Learn ways in which insect pests are controlled (to be followed by more info in classroom)

Pests in stored seeds

- Introductory info
- Example of trial in Asia

Magnitude of pest damage in stored grain

- In Kenya, up to 30% of maize grain lost to pests during storage
- In West Africa, up to 100% of cowpea lost to cowpea bruchids (*Callosobrachus maculatus*)

Sallam, M.N. 1999. Insect Damage: Post-harvest Operations. INPhO—Post-Harvest Compendium, FAO

Main types of insect pests in stored seed

- Coleoptera (beetle family)
  - *Most destructive of stored grain pests*
  - *Primary pests --attack intact grains, with larvae that feed within grain kernels*
    - Snout beetles: Rice (*Sitophilus oryzae*) and maize *(S. zeamais*) weevils
    - Bruchids: Cowpea weevil (*Callosobruchus maculatus*)
  - *Secondary pests —attack damaged kernels*
    - Flour beetles: Red-rust (*Tribolium castaneum*) and Confused (*Tribolium confusum*) Flour beetles
    - Saw-toothed grain beetle (*Oryzaephilus* sp.)

Coleoptera examples at ECHO

Cowpea weevil

Saw-toothed grain weevil

Main types of insect pests in stored seed

- Lepidoptera (moths and butterflies)
  - *Adults have wings; caterpillar larvae have mandibles for chewing*
  - *Moths often lay eggs in the field that then infest stored seed*
- Examples
  - *Pyralidae —warehouse (Ephestia sp.) and meal (Plodia interpunctella) moths*
  - *Gelechiidae —Angyoumois grain moth (Sitotroga cerealella)*

Sallam, M.N. 1999. Insect Damage: Post-harvest Operations. INPhO—Post-Harvest Compendium, FAO

Pest control options—an ECHO Asia trial

- Purpose was to evaluate locally available seed treatments for controlling cowpea bruchids.

- These insects lay their eggs in the field, which then hatch in harvested/stored cowpea

ECHO Asia cowpea bruchid trial

Control options trialed (4 reps; in RCBD)

No.	Vacuum	Seed treatment
1	Sealed at 0.8 Mpa	Non-treated control
2	Sealed at 0.8 Mpa	Bleach (1%)
3	Sealed at 0.8 Mpa	Botanical (galangal powder)
4	Sealed at 0.8 Mpa	Carbaryl powder (10%)
5	Sealed at 0.8 Mpa	Charcoal (bamboo)
6	Sealed at 0.8 Mpa	Detergent powder
7	Sealed at 0.8 Mpa	Vegetable oil
8	Sealed with no vacuum	Non-treated control
9	Sealed with no vacuum	Bleach (1%)
10	Sealed with no vacuum	Botanical (galangal powder)
11	Sealed with no vacuum	Carbaryl powder (10%)
12	Sealed with no vacuum	Charcoal (bamboo)
13	Sealed with no vacuum	Detergent powder
14	Sealed with no vacuum	Vegetable oil

ECHO Asia cowpea bruchid trial

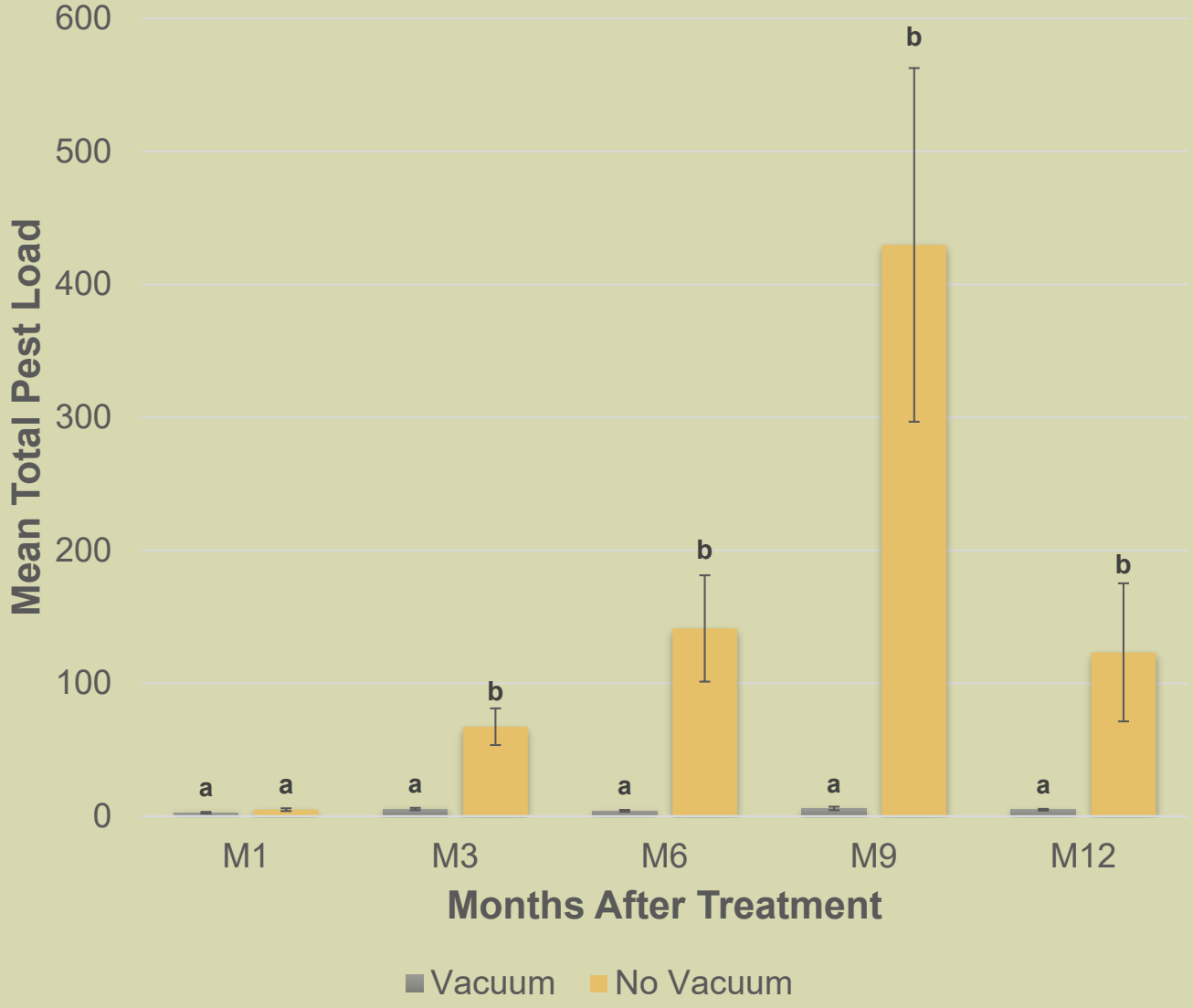
Variables measured

- Seed lots taken out of the cold room at 1,3, 6, 9, and 12 months

- Data
  - *Bruchid pest load (sum of eggs, holes/windows, & adults)*
  - *Seed viability —germination*

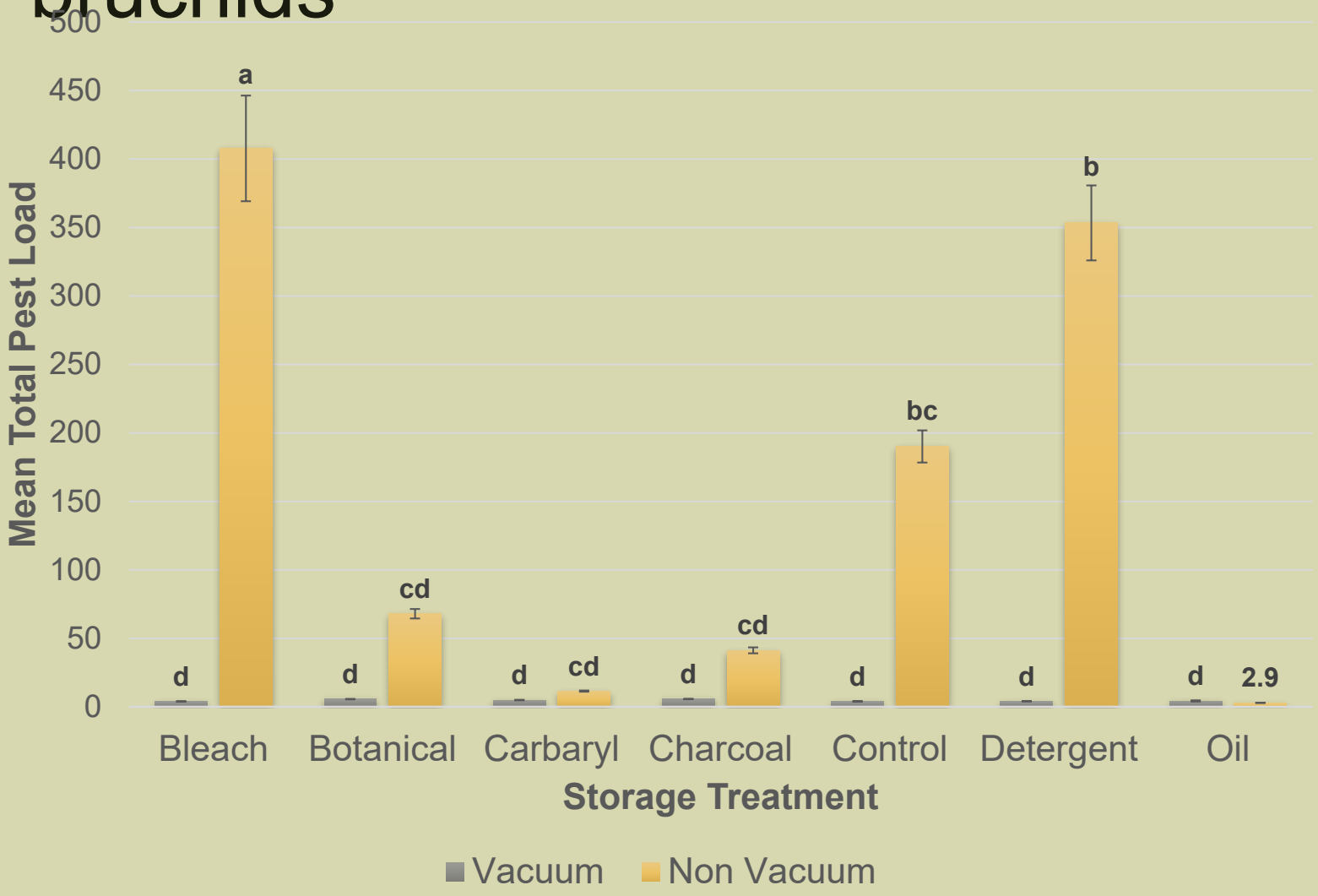
ECHO Asia cowpea bruchid trial

Vacuum sealing greatly reduced pest load



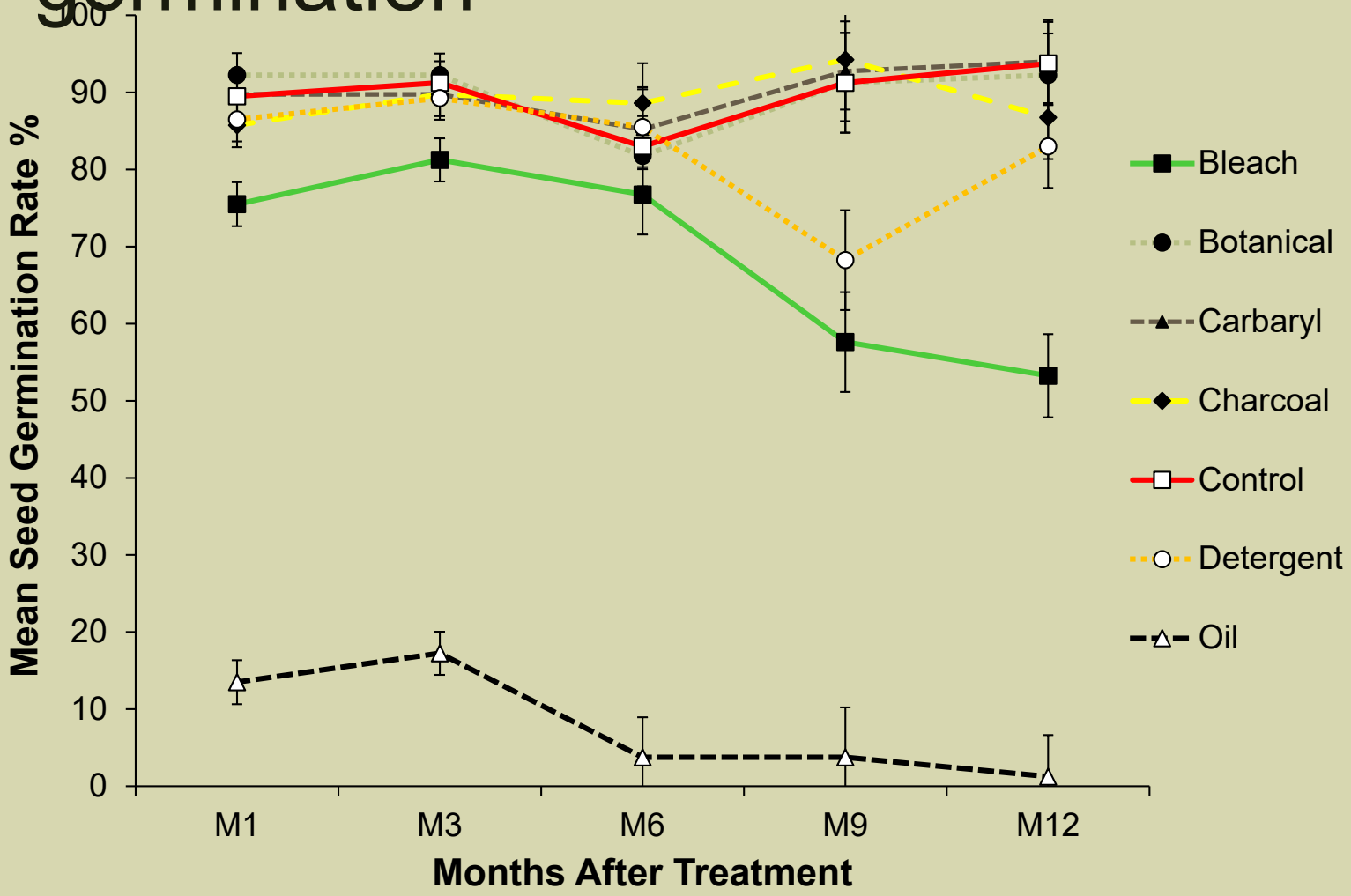
ECHO Asia cowpea bruchid trial

Effect of local treatments on bruchids



ECHO Asia cowpea bruchid trial

Treatment effects on seed germination



Conclusions of cowpea bruchid trial

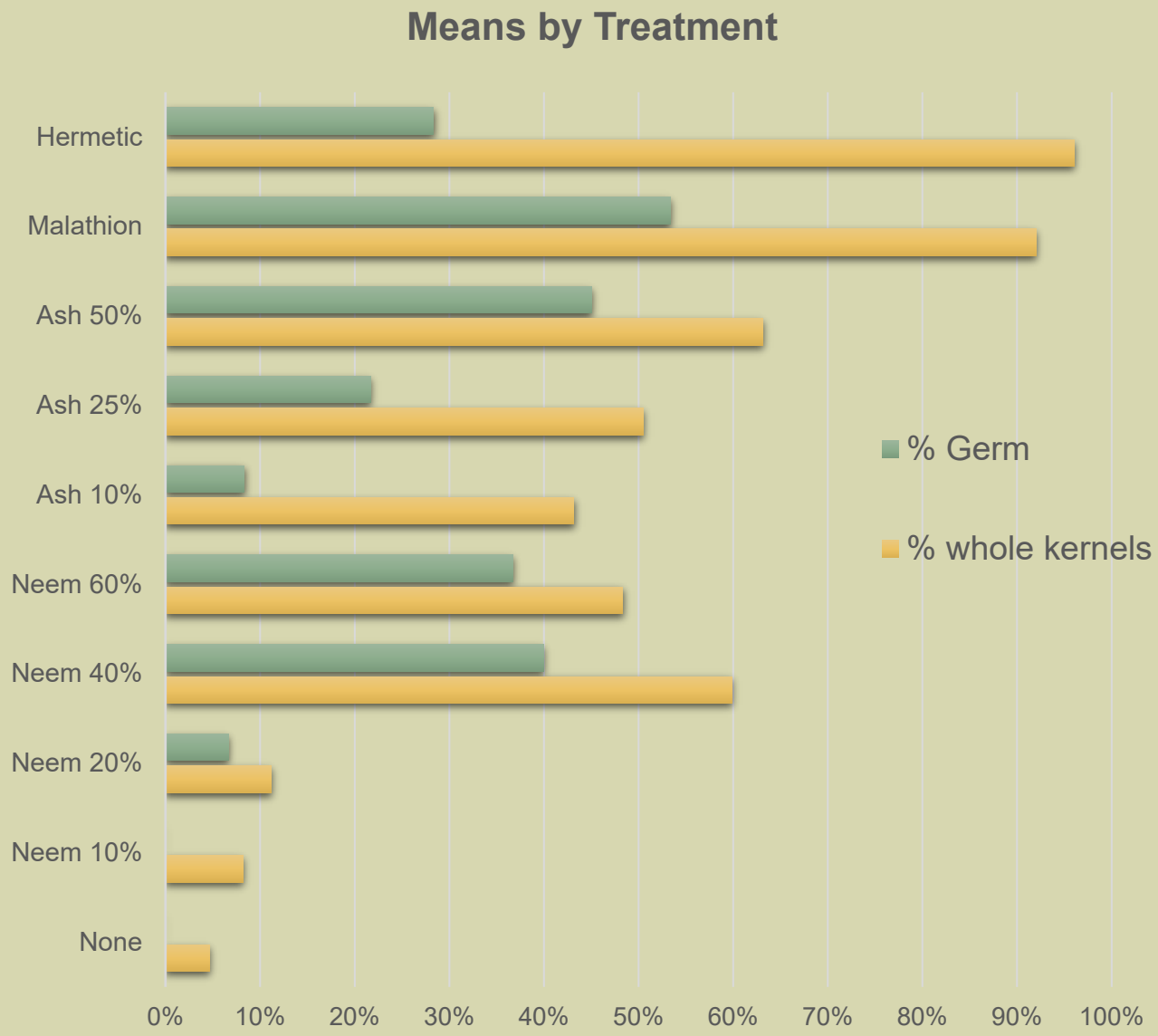
- Vacuum sealing holds promise as an affordable and effective means of bruchid control, as well as maintaining viability of stored seed.

- Several commonly available seed treatments also showed potential for deterring bruchids, without adversely affecting seed viability.

Full-text online article URL: http://rdcu.be/pD4b

Lawrence, B., A. Bicksler and K. Duncan. 2017. Local treatments and vacuum sealing as novel control strategies for stored seed pests in the tropics. Agronomy for Sustainable Development 37:6

Botanical treatments\ from Neil Miller at ECHO in East Africa



Pest management in grain for consumption

Insights from Floyd Dowell

RECALCITRANT SEEDS

Supplemental content

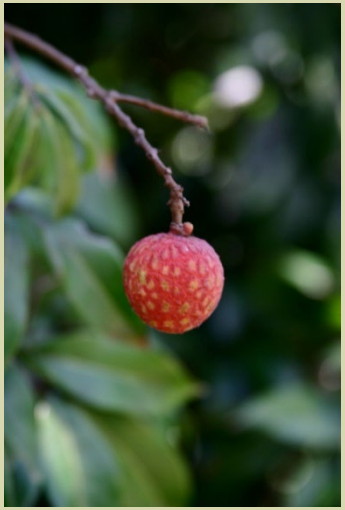
Underlying principle

To keep in mind when dealing with recalcitrant seeds

- Unlike orthodox seeds, recalcitrant seeds do not enter a rest/dormant phase prior to germination. Many of the tropical fruits come from forests with conditions (high temp and humidity) conducive to germination all year long. Thus, metabolic processes must be active. Long term storage of recalcitrant seeds is not possible, but there are some ways to extend the life of recalcitrant seeds.

Recalcitrant fruits- examples

- *Artocarpus heterophyllus:* jack fruit
- *Cocos nucifera:* coconut
- *Litchi chinensis:* lychee
- *Mangifera indica:* mango
- *Persea americana* : avocado
- *Theobroma cacao: c* ocoa tree

Temperature

- Must be high enough to support respiration

- Varies depending on the fruit.
  - *Some (mostly temperate species) can be kept just above freezing to extend storage life; consult the literature, as such cool temps will actually shorten the life of many fruit seeds.*
  - *Room temperature or slightly below is often best for tropical fruits. For instance, Warrier et al (2009) found that jackfruit seeds stored at 20 °C retained viability for 5 weeks with 41% germination.*

Warrier, R.R. et al. 2009 Standardization of Storage Conditions to Prolong Viability of Seeds of Artocarpus heterophyllus Lam-A Tropical Fruit Tree. ARPN J of Ag & Bio Sci:4:6-9

Humidity and oxygen

- Needs to be high enough to keep seeds at least as moist as they were on the tree. Fresh seed moisture content varies (e.g. 36% for rubber to 90% for chayote [*Sechium edule*]) depending on species, cultivar and seed lot (Hong et al. 1996)
- Consequently
  - *Rewetting of seeds may be needed during storage*
  - *Relative humidity needs to be kept at 96% to 99%.*
- Choose containers that prevent moisture loss but allow some gas exchange with the atmosphere (Bonner 2008). Plastic bags with wall thickness of 3 to 7 mils okay (Ziploc freezer bags are 3 to 4 mils thick). Oxygen needed to maintain metabolism.

Bonner, F.T. 2008. Storage of Seeds (Ch 4). In: Woody Plant Seed Manual, USDA FS Ag Handbook 727

Hong, T.D. et al. 1996. Seed Storage Behavior: a Compendium. Handbooks for Genebanks: No. 4. International Plant Genetic Resources Institute, Rome

Storage media

- Needs to keep seeds moist

- Options to consider are damp/moist
  - *Sphagnum moss (ECHO's seed bank uses this for jack fruit seed)*
  - *Charcoal*
  - *Sawdust*
  - *Sand*

How to minimize fungal disease

In storing recalcitrant seeds

- Try surface sterilization
  - *Could experiment with bleach/water*
  - *To avoid harming the embryo, use low concentration (10% or less) and duration (e.g., brief dip)*
- Use distilled/deionized water in keeping seeds moist
- Remove the pulp surrounding the seeds
- Plant seeds as soon as possible

Be aware of “intermediate” seeds with regards to storage behavior

- Papaya and neem
  - *Can be dried like an orthodox seed*
  - *But, best stored at room temperature*

- Lemon (*Citrus limon*)
  - *Can be stored up to 2 years, like orthodox seed*
  - *But, it is sensitive to desiccation*

- Black sapote can be stored dry but storage life is only a few months

Other ways to minimize pests

- Minimize insect pests in the field
  - *Follow Integrated Pest Management strategies*
  - *Clean grain storage spaces, especially if they are close to farmers' fields*

- Damaged kernels are susceptible to pests (especially secondary pests like saw-toothed grain beetles); adopt cleaning/transport practices that don't damage seeds

- Maintain dry conditions to limit fungal problems

- Can try placing seeds in a freezer—works for many orthodox seeds (do a germination test with a small sample if unsure) but may not be an option for many farmers

Literature on seed storage

- ECHO Website (www.ECHOcommunity.org; see “Publications” tab)
  - Technical Note: Seed Saving Steps & Technologies
  - Best Practices Note: Seed Storage in the Tropics
  - EDN 86: Extending the Life of Your Seeds
  - EDN 109: Reducing Moisture Content of Seeds Prior to Storage
  - ECHO Asia Notes Issue 14: Vacuum sealing versus refrigeration
  - Info on making a vacuum pump from a bicycle tire pump

- Online:
  - Seed and seed genebanks –Crop Genebank Knowledge Base
  - Bioversity International- has a link to Compendium of Information on Seed Storage Behavior
  - Dessication tolerance and seed storage conditions for many fruit species—Appendix 1 in Collection, Storage and Treatment of Tree Seeds (FAO)
  - Storage life of tropical fruits in Growing Rare Fruit from Seed
  - Insect Damage: Post-harvest Operations