Handling

I. Drying and Extracting

A. Introduction

Like agricultural seeds, many tree fruits dry as they mature, and seeds are extracted best at low moisture contents. Other tree seeds are still very moist at maturity, and special considerations are needed for extraction. No matter what type of fruit is involved, however, the objective of extraction is to obtain the maximum amount of seeds in the best physiological condition in an economically efficient operation. During extraction, seed quality can be greatly reduced by excessively heating the fruit to force opening or by extracting by hand or machine.

B. Objectives

1. Recognize potential problems of seed extraction related to the type of fruit.
2. Identify the basic techniques of tree seed drying and extraction.

C. Key Points

The following points are essential to seed drying and extracting:

1. For species that require drying, excessive heat in the presence of high moisture content can be deadly.
2. Seed damage can occur during mechanical separations.
3. Good training of workers is essential.
4. Extraction strategy depends on the type of fruit involved.

D. Multiseed Fruits

Multiseed fruits include pods; moist, fleshy fruits; and cones and capsules. Each type requires different steps to extract the seeds:

1. **Pods**
   - a. Dry the fruits.
   - b. Thresh manually by:
     - (1) Flailing with poles
     - (2) Crushing by trampling
     - (3) Hitting with heavy mallets
   - c. Thresh mechanically by:
     - (1) Slow, rotating drums (cement mixer)
     - (2) CSIRO flailing thresher
     - (3) Dybvig macerator
     - (4) Hammer mills or other flailing devices
   - d. Use a series of steps for difficult species.
2. **Moist, fleshy fruits**
   - a. Start quickly to avoid fermentation.
   - b. Soak in water.
   - c. Extract with macerators, mixers, coffee depulpers (*Gmelina arborea),* feed grinders, hammer mills, etc.
   - d. Run small fruits (e.g., *Rubus* and *Morus)* in blenders at slow speeds with lots of water.
   - e. Use water extraction with a high-pressure stream.
3. **Cones, capsules, and other multiple fruits**
   - a. Air-dry on flat surfaces.
     - (1) Canvas is best for large quantities.
     - (2) Screen trays are good for smaller lots, such as single-tree collections.
     - (3) Plastic sheets are not strong enough for *Pinus* cones **(1 hL** of cones equals 35 kg).
     - (4) Protect the drying fruits from rain and predators; spread thin and stir frequently.
     - (5) Dry some species under shade (e.g., *Hopea* spp., *Triplochiton schelroxylon,* and *Pinus oocarpa).*
   - b. Use solar kilns.
     - (1) Simple type (clear polyethylene stretched over a frame)
     - (2) Solar heat storage units (more sophisticated)
   - c. Use heated kilns for large quantities of cones; some types are:
     - (1) Progressive (cone containers are moved along a gradient of increasing temperature)
     - (2) Large batch (large, heated chambers in which trays hold cones and rotate positions)
     - (3) Small batch (wire-bottom drawers that hold about one-third hL of cones each)
     - (4) Stack trays (wooden trays with perforated sheet-metal bottoms, not wire screens, in stacks of six with eight stacks heated with one heating system)
     - (5) Tumbler driers (cylindrical batch kilns that rotate while drying)
     - (6) Other batch kilns (many local designs available)
   - d. Set temperature and humidity parameters. The object is to remove moisture; high temperatures create a greater vapor pressure gradient. Some recommended parameters are 29 to 50 °C for conifers, and 8 hours at 60 °C for *Eucalyptus saligna.* Use a 15-second dip in boiling water for serotinous cones to melt the resin before placing them in the kiln.
   - e. Extract the seeds after the cones are open with:
     - (1) Tumbler driers
     - (2) Cement mixers
     - (3) Homemade tumblers

E. Single-Seed Fruits

Single-seed fruits include drupes (e.g., *Prunus* and *Vitis)* and nuts.

1. For drupes or other fleshy fruits, use macerators, mixers, etc.
2. For nuts with husks, use macerators or hand rubbing.

F. Sources

For additional information, see Willan 1985, p. 87-111.

II. Cleaning and Upgrading

A. Introduction

Cleaning seedlots is a basic step in proper seed utilization. Cleaning should remove wings or other seed appendages, empty seeds, damaged seeds, and nonseed trash. This cleaning should also provide dramatic decreases in insect and disease problems. Many seedlots can be upgraded by removing immature, damaged, and dead seeds after the initial cleaning. Many people view large mechanical operations as the only way to clean and upgrade seedlots, but seedlot quality can be improved with simple equipment and techniques.

B. Objectives

1. Learn the advantages of cleaned and upgraded seedlots.
2. Become familiar with the principles of seed-cleaning equipment and techniques.
3. Apply these principles when seed cleaning and upgrading are planned.

C. Key Points

The following points are essential for seed cleaning and upgrading:

1. Liquid flotation can be an essential aid for many species, especially recalcitrant ones.
2. Screen cleaning is the basic seed-cleaning method.
3. Air separation, including winnowing, is a valuable technique.
4. Cleaning small lots for testing or research may be very different from cleaning large lots.
5. Upgrading seedlots offers potential improvements in eight areas.
6. Seed sizing can be useful for some species or sources but not for others.

D. Cleaning

1. **Flotation —The** simplest method of all.
    a. Initial moisture content is crucial.
    b. Orthodox seeds are redried after flotation, but recalcitrant seeds are not.
    c. Flotation
        (1) Removes light trash.
        (2) Removes many empty, broken, diseased, or insect-damaged seeds.
        (3) Is very good for large seeds with high moisture contents.
2. **Aspirators—Any** machine that uses air to clean and separate:
    a. Large-scale machines in seed plants
    b. Small-lot cleaners for testing laboratories and research
    Some types are:
        (1) General ER
        (2) South Dakota
        (3) Stults
        (4) Barnes
        (5) Other models as described by Willan 1985
        (6) Homemade fan devices
        (7) Carter Day Duo Aspirator
3. **Screens and sieves—** There are two types of screening devices:
    a. Hand screens
    b. Mechanical screen cleaners
4. **Air-screen cleaners —** These are the basic seed-cleaning machines in most seed plants. They combine aspiration and screening. Even small models can clean 30 to 40 kg of small seeds per hour. Important principles to remember are:
    a. They perform three functions:
        (1) Scalping
        (2) Sizing
        (3) Aspiration
    b. They are more efficient as cleaners, not as sizers.
5. **Electrostatic cleaners—** The Helmuth machine is good for very small seeds.
6. **Dewinging—** A special type of cleaning that reduces storage volume, makes upgrading possible, makes sowing easier, and removes pathogens. There are two basic methods of dewinging— wet and dry.
    a. The dry method is recommended for tough seeds only because of the damage potential to thin seed coats. Dry dewingers include:
        (1) Popcorn polishers
        (2) Missoula Equipment Development Center dewinger
        (3) Dybvig
        (4) Electric drum
        (5) New conifer dry dewingers
    b. The wet method is usually preferred for conifers. Wet dewingers include:
        (1) Cement mixers
        (2) Commercial dewingers
        (3) Kitchen blenders (for small lots)
        (4) Any cylinder with gentle agitation

E. Upgrading

1. **Upgrading** is improving the potential performance of a seedlot by removing empty, damaged, weak, immature, or odd-sized seeds.
2. **Upgrading will:**
   a. Remove weak seeds
   b. Remove empty seeds
   c. Reduce chances of insect and disease damage
   d. Improve control of density in nursery
   e. Reduce planting time
   f. Facilitate nursery operations
   g. Reduce costs and improve uniformity
   h. Reduce storage space requirements
3. **Methods and equipment**
   a. Specific gravity by flotation uses:
      (1) Water for some *Pinus, Quercus,* and other large seeds
      (2) Organic solvents (usually alcohols) of different densities for some small seeds
   b. Air-screen cleaners:
      (1) Separate by three physical properties
      (2) Upgrade by sizing or by removing empties with air
      (3) Regulate screen pattern, feed rate, airflow, screen oscillation (pulleys), and screen pitch (in some models)
   c. Air separators include:
      (1) Large air-column separators
      (2) Fractionating aspirators
      (3) Small laboratory blowers
   d. Gravity separators were originally built to remove ore from clay. They:
      (1) Can separate seeds of the same size and different densities or different sizes and the same density.
      (2) Are widely used on conifer seeds in North America.
      (3) Regulate feed rate, air stream through deck, deck pitch (side and end), and eccentric thrust.
   e. Electrostatic separators create a charge that adheres to the seed surfaces. Models include:
      (1) Helmuth cleaner for *Eucalyptus* and conifers of the Western United States.
      (2) Static electricity for very small seeds. The sides of a plastic beaker are wiped with a nylon cloth.
   f. Radiography is used for valuable research lots only.
   g. Color separators remove light-colored seeds.
   h. Incubation, drying, and separation (IDS) method —A new method from Sweden that is used on *Pinus* and *Picea.*
4. **Sizing** helps with some species or seedlots, but not with others; e.g., single family seedlots.

G. Sources

For additional information, see Bonner 1987b; Doran and others 1983, chap. 5; Willan 1985, p. 87-128.

III. Storage Principles

A. Introduction

The primary purpose of storing seeds is to have a viable seed supply when it is needed for regeneration. Successful storage of woody plant seeds must be carefully planned, and good planning depends on an understanding of the purposes of storage, of seed deterioration, and of the effects of the storage environment on the deterioration processes.

B. Objectives

1. Learn the objectives and rationale of seed storage.
2. Identify factors that affect seed longevity in storage.
3. Review the general process of seed deterioration.

C. Key Points

The following points are essential to understanding seed storage principles:

1. Longevity of seeds is a species characteristic.
2. Prestorage factors affect longevity in storage.
3. The most important factors in storage are seed moisture content and temperature.
4. Seed deterioration begins at abscission and involves complex physiological changes.

D. Objective of Storage

The objective of storage is to delay deterioration or decrease its rate until seeds are used.

E. Rationale for Storage

Storage may be short- or long-term; it may be extended for long periods for germplasm conservation.

1. **Short-term storage:**
   a. Is used for immediate operations
   b. Typically lasts less than 5 years
   c. Allows carry-over of surplus production
   d. Requires minimum storage space requirements
2. **Long-term storage:**
   a. Typically lasts from 5 to 10 years
   b. Ensures constant seed supply

c. Saves special lots that will not be collected annually
d. Requires very good storage environments

3. **Germplasm conservation**
   a. If storage is planned for 50 years or more
   b. Requires the very best storage environment

F. Longevity in Storage

Many factors affect seed longevity in storage:

1. **Seed characteristics**
   a. Basic physiology
      (1) Orthodox seeds are tolerant of desiccation to low moisture contents.
      (2) Recalcitrant seeds are intolerant of desiccation.
   b. Seed structure — Thick or hard seedcoats restrict moisture uptake and gas exchange.
   c. Seed chemistry — Oily seeds tend to be harder to store than starchy seeds.
   d. Stage of maturity—Immature seeds usually will not store as well as fully mature seeds.
   e. Environmental stress—Stress during maturation can affect longevity.
2. **Seed handling before storage**
   a. Physiological mistreatment can damage storage potential.
   b. Processing damage will lower seed quality.
3. **Genetics — Good** seed quality is inherited to some degree.
4. **Storage environment**
   a. Moisture content
      (1) Moisture content is the most important factor.
      (2) Potential damage thresholds are outlined in table 5.
      (3) The best range for orthodox seeds is 5 to 10 percent.
      (4) The best range for recalcitrant seeds is full imbibition.

Table 5. —*Moisture content thresholds and potential effects on stored seeds*

Moisture content	Effects
Percent	
>30	Germination begins
18 to 20	Overheating from respiration
10 to 18	Seed fungi become active
>9	Insect activity
5 to 8	Best range for sealed storage
<5	Desiccation damage possible in some species

Table 6. —*Equilibrium moisture contents at 4 to 5 °C and three relative humidities (Bonner 1981b, Justice and Bass 1978)*

	Relative humidity		
	Percent ----		
Species	20	45	95
	Moisture content		
	Percent ----		
Orthodox trees			
Carya ovata		10	15
Juglans nigra		11	20
Liquidambar styraciflua		8	20
Liriodendron tulipifera		10	19
Picea abies	6	8	
Pinus sylvestris	6	8	
P. taeda		10	17
Prunus serotina		9	17
Orthodox crops			
Glycine max	6	8	19
Zea mays	8	12	20
Recalcitrant trees			
Quercus alba		37	50
Q. nigra		13	29
Shorea robusta			35

Data not available.

      (5) The equilibrium moisture content is defined as the seed moisture content when seed moisture is in equilibrium with the moisture in the storage atmosphere (table 6). Equilibrium moisture content:
         (a) is influenced by seed chemistry (fig. 9)
         (b) is rarely reached with recalcitrant seeds
         (c) has sorption and desorption differences
   b. Temperature
      (1) Generally, the cooler the seeds, the slower the deterioration rate.
      (2) The safe temperature range for orthodox seeds is related to the moisture content of the seeds:
         (a) Orthodox seeds at 5- to 10-percent moisture can be stored at most temperatures.
         (b) Between 50 and 0 °C, every 5 °C lowering of storage temperature doubles the life of the seeds (Harrington 1972).
      (3) The safe temperature ranges for recalcitrant seeds are:
         (a) Temperate Zone species: —1 to 3 °C.
         (b) Tropical species: usually above 12 to 15 °C.

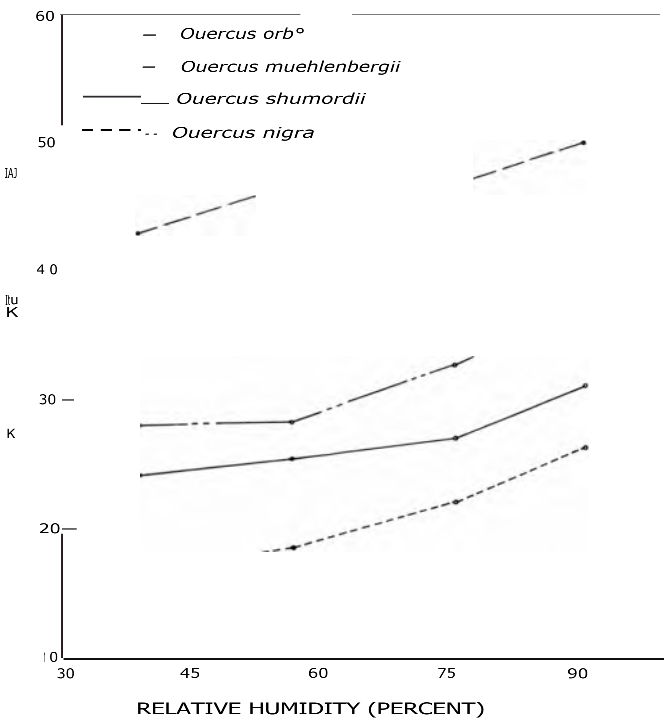

Figure 9. —*Equilibrium moisture content at 25 °C for four recalcitrant* Quercus *species (adapted from Willan 1985).*

c. Storage atmosphere

(1) If oxygen levels are reduced, metabolism is slowed, which can increase longevity.

(2) Inert gases offer no advantage in long-term storage, but they may help in short-term storage.

(3) In sealed containers, the CO_2/O_2 ratio changes.

G. Cells and Tissues During Seed Aging

The following changes occur in cells and tissues during aging:

1. Loss of food reserves
2. Accumulation of metabolic byproducts
3. Irreversible enzyme deactivation
4. Deterioration of cell membranes
5. Lipid peroxidation
6. Alterations of DNA

H. Sources

For additional information, see Bonner and Vozzo 1990; Harrington 1972; Justice and Bass 1978; Tang and Tamari 1973; Willan 1985, p. 129-160.

IV. Storage Applications

A. Introduction

The previous section introduced the principles and critical factors that influence seed longevity. This section discusses how these principles are applied in practice to store tree seeds.

B. Objectives

1. Relate seed storage principles to prescriptions for each species group.
2. Learn features of cold storage units.
3. Discuss storage constants and their application.
4. Learn basic principles of seed management in storage.

C. Key Points

The following points are essential to storage applications:

1. There are four classes of seed storage behavior.
2. Cold storage is best but not always necessary for successful seed storage.
3. Each species, and perhaps individual populations within a species, will nearly always respond identically to a given type of storage conditions.
4. Good facilities and good seeds are not enough; good management is essential for optimum seed storage operations.

D. Seed Storage Classes

There are four classes of tree seed storage behavior (table 7):

1. **True orthodox**

a. True orthodox seeds are tolerant of desiccation (table 8) and:

(1) Can be dried to moisture levels of 5 to 10 percent.

(2) Can be stored at subfreezing temperatures.

(3) Are easily stored for at least one rotation.

(4) Have generally unknown upper limits of storage.

b. Examples include most of the valuable temperate genera *(Pinus, Picea, Betula, Prunus)* and many tropical genera *(Acacia, Eucalyptus,* and *Casuarina).*

2. **Suborthodox**

a. Suborthodox seeds are similar to true orthodox seeds but are limited to shorter periods (table 9).

(1) They are stored under the same conditions as true orthodox seeds.

(2) They are limited in storage potential because of high lipid contents, thin seedcoats, or genetic makeup.

b. Examples include those with high lipid content *(Juglans, Carya,* some *Abies,* and *Pinus),* those with thin seedcoats *(Populus* and *Salix),* and some whose genetic makeup requires slow drying *(Fagus* and *Citrus).*

Table 7. —*Storage conditions for four storage classes of tree seeds*

Storage class	Storage period	Seed moisture	Temperature	Container type
	Years	Percent	°C	
True orthodox	<5	6-10	0-5	Airtight
	>5	6-10	—18	Airtight
Suborthodox	<5	6-10	0-5	Airtight
	>5	6-10	—18	Airtight
Temperate recalcitrant	<3	30-45	—1 to —3	4-mil* plastic, unsealed
Tropical recalcitrant	<1	30-45	12-20	4-mil plastic, unsealed

*mil = 1/1000 inch = 0.025 mm.

Table 8. —*Storage test results for true orthodox species (adapted from Bonner 1990)*

Species	Storage conditions: Temperature	Storage conditions: Seed moisture	Storage results: Time stored	Storage results: Viability loss
	°C	*Percent*	*Years*	*Percent*
Abies procera	*0*	9	7.0	11
Acacia leptopetala	20–25		18.0	1
A. mangium	4–8		1.2	6
A. pruinocarpa	20–25		16.0	20
Acer saccharum	*—10*	10	5.5	5
Albizia falcataria	4–8		1.5	10
Araucaria cunninghamii	*—15*	16–23	8.0	few*
A. cunninghamii	19	7	0.1	0
Casuarina equisetifolia	– 3	6–16	2.0	0–5
C. torulosa	20–25	8–12	18.0	6
Liquidambar styraciflua	3	5–10	9.0	3
Pinus caribaea var. *hondurensis*	8		2.7	±16
P. elliottii	4	10	50.0	30
P. merkusii	4-5	<8	4.0	0
P ponderosa	0	8	7.0	0
Tectona grandis	0–4	–12	7.0	0
Tsuga heterophylla	5	8	2.0	0
T. heterophylla	– 18	8	2.0	0

"Data not available.
*Exact value not available from original source.

Table 9.—*Storage test results for suborthodox species (adapted from Bonner 1990)*

Species	Storage conditions: Temperature	Storage conditions: Seed moisture	Storage results: Time stored	Storage results: Viability loss
	°C	*Percent*	*Years*	*Percent*
Citrus limon	*—20*	a	0.9	±5
Fagus sylvatica	*—10*	10	5.0	34
Gmelina arborea	*—5*	6–10	2.0	10
Populus deltoides	–20	6–10	6.0	21
Salix glauca	– 10	6-10	1.2	0

3. **Temperate recalcitrant**

a. Temperate recalcitrant seeds are intolerant of desiccation (table 10)

(1) They cannot be dried below 20- to 30-percent moisture; therefore, storage must be above freezing.

(2) They have metabolisms so rapid that pregermination commonly occurs in storage.

(3) They cannot be stored in airtight containers; there must be some gas exchange (table 7).

b. Examples include *Quercus* and *Aesculus.*

4. **Tropical recalcitrant**

a. Tropical recalcitrant seeds are the same as temperate recalcitrant seeds but are sensitive to low storage temperatures (table 11). They experience chilling damage and death below 12 to 20 °C.

b. They are the most difficult group of all to store.

c. Examples include *Shorea, Hopea,* and *Dipterocarpus,* and even some legumes *(Pithocellobium* spp. in Costa Rica).

Table 10. —*Storage test results for temperate recalcitrant species (adapted from Bonner 1990)*

Species	Storage conditions: Temperature	Storage conditions: Seed moisture	Storage results: Time stored	Storage results: Viability loss
	°C	*Percent*	*Months*	*Percent*
Acer saccharinum	—3	50	18	8
Quercus falcata var. *pagodaefolia*	3	35	30	6
Q. robur	—1	40-45	29	31-61
Q. rubra	—1 to —3	38-45	17	18-46
Q. virginiana	2		12	35

* Data not available

Table 11. — *Storage test results for tropical recalcitrant species (adapted from Bonner 1990)*

Species	Storage conditions: Temperature	Storage conditions: Seed moisture	Storage results: Time stored	Storage results: Viability loss
	°C	*Percent*	*Days*	*Percent*
Araucaria hunsteinii	19.0	25-30	54	± 30
A. hunsteinii	2.0	30	365	82
Azadirachta indica	26.0	10-18	56	65
Hopea helferi	15.0	47	37	2
Shorea robusta	13.5	40-50	30	60
S. roxburghii	16.0	40	270	±30

E. Cryogenic Storage

Cryogenic storage is a method for very long-term storage for germplasm conservation (table 12).

1. **Techniques**

a. Packages are immersed in liquid nitrogen (—196 °C) or suspended above it in the vapor.

b. It has potential for small quantities only.

c. Maximum time limits are not known. Only a few tests have been made on tree seeds.

2. **Costs —** Costs are comparable with conventional storage in some cases.

F. Physical Facilities

1. **Cold storage units**

a. Cold storage units require a reliable power source, should not be built where floods or earthquakes are likely, should be located near other seed activities, should be rodent proof, and should be on high elevations when possible because ambient temperatures will be cooler.

b. Units should be built to hold a 5-year supply.

c. For germplasm conservation, about 1 liter is needed of each sample; e.g., 85 m^3 should hold 22,800 samples.

d. Humidity control is not recommended in the Tropics.

e. Direct or indirect vapor-compression refrigeration is recommended.

f. Standby generators are needed.

g. Thermal time constants of 4 to 5 days should apply in large coolers.

h. Modular panel units are effective.

i. Insulation depends on ambient conditions.

Table 12. —*Storage test results for cryogenic trials of forest tree seeds (adapted from Bonner 1990)*

Species	Seed moisture	Time stored	Viability loss
	Percent	*Days*	*Percent*
Abies alba		6	5
A. concolor	<13	180	0
Fagus syluatica		6	100
Larix decidua		6	5
Picea abies		6	1
Pinus echinata		112	0
P ponderosa	<13	180	0
P. syluestris		6	0
Populus tremula x *tremuloides*		6	1
Ulmus pumila		112	0

Data not available

2. **Containers**
   a. Fiber drums
   b. Rigid plastic containers, which are better than glass
   c. Rectangular containers
   d. Plastic bags
3. **Moisture management**
   a. Seeds will reach an equilibrium moisture content when exposed to the storage atmosphere.
   b. With humidity control (50 to 60 percent relative humidity), orthodox seeds need not be sealed. Recalcitrant seeds cannot be sealed, so they cannot be stored in such a unit.
   c. Without humidity control (>95 percent relative humidity), recalcitrant seeds store well. Orthodox seeds must be dried and stored in sealed containers.
   d. Humidity controls are not recommended for the Tropics.
   e. Frost-free refrigerators are an inexpensive alternative for small quantities.

G. Genetic Damage in Long-term Storage
1. Would be devastating to seeds stored for germplasm conservation, but there is no strong evidence to date of lasting damage.
2. Could cause changes in the population.

H. Retesting in Long-term Storage

For retesting in long-term storage:
1. Use ISTA rules or comparable procedures.
2. Use the following test interval for orthodox seeds: initial year, third year, and every fifth year thereafter.
3. Ensure nondestructive testing.
4. Regenerate when viability falls to 50 percent.

I. Viability Constants in Storage
1. **Theory—Viability** retention will be the same for a given species under a given set of storage conditions.
2. **Practice**
   a. Results are good with some agricultural seeds.
   b. Varieties of a single species may differ.
   c. One must start with very good seeds.
   d. There are few data for tree seeds.
3. **Viability constants—If** valid, they could be very useful in planning long-term storage for germplasm conservation.

J. Sources

For additional information, see Bonner and Vozzo 1990; Chin and Roberts 1980; Harrington 1972; International Board for Plant Genetic Resources 1976; Justice and Bass 1978; Roberts 1973; Tang and Tamari 1973; Willan 1985, p. 129-160.