COLLECTION AND CARE OF ACORNS

A Practical Guide For Seed Collectors And Nursery Managers

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The biological characteristics of acorns present acute problems in the collection and care of these single-seeded fruits. Acorns collected too soon before physiological maturity will seldom germinate normally. Another critical factor is the high natural moisture content of acorns and extreme sensitivity to desiccation that they exhibit when dried only slightly below these high moisture levels. Maintaining this high natural moisture content is the key to maintaining good acorn quality, both in transport and in storage.

The information that follows will tell readers how to estimate seed crops; how to collect, clean, and store acorns; how to perform simple test of seed quality on acorns; and how to prepare acorns for planting. The first section is an illustrated, practical "how-to-do-it" guide. The second section presents more detailed information in previously published materials, with links to the individual publications. The primary emphasis is on oaks of the southeastern United States, but many of the principles apply to oaks throughout the world. These publications (by the author and others) have been shortened and editted in several places. They are non-copyrighted government publications that may also be obtained free of charge from U.S. Forest Service offices. Internet links to websites that specialize in seed testing, nursery operations, and other technical information are also listed for those who wish this additional information. To move from page to page and to access the various references, readers must click on the hyperlinks provided.

Table of Contents

Section I— How to collect and care for acorns

Section II—Reference materials

To go directly to the listed materials, right-click on the highlighted numbers & letters.

Seed biology and technology of *Quercus*. F.T. Bonner and J.A. Vozzo. 1987. USDA Forest Service. GTR SO-66. 21 p. (SO-66)

The effect of damaged radicles of presprouted red oak acorns on seedling production. F.T. Bonner. 1982. Tree Planters' Notes. 33(4): 13-15. (TPN33)

Testing for seed quality in southern oaks. F.T. Bonner. 1984. USDA Forest Service. Res. Note SO-306. 6 p. (SO-306) (SO-306)

Measurement and management of tree seed moisture. F.T. Bonner. 1981. USDA Forest Service. Res. Pap. SO-177. 10 p. (excerpts only) (SO-177)

Storage technique affects white oak acorn viability. G. Rink and R.D. Williams. 1984. Tree Planters' Notes. 35(1): 3-5. (TPN35)

Insects and fungi associated with acorns of *Quercus* sp. J.A. Vozzo. 1984. In: Yates, H.O. III, compl. and ed., Proceedings, cone and seed insects working party conference; 1983 July 31-August 6; Athens, GA. Asheville, NC: USDA Forest Service, Southeastern For. Expt. Sta.: 40-43. (IUFRO)

Insects that damage white oak acorns. L.P. Gibson. 1972. USDA Forest Service. Res. Pap. NE-220. 7 p. (NE-220)

Insects that damage northern red oak acorns. L.P. Gibson. 1982. USDA Forest Service. Res. Pap. NE-492. 6 p. (NE-492)

Internet contacts for other sources of information. (contacts)

Section I—INTRODUCTION

The fruits of the genus *Quercus* are single-seeded nuts (Olson 1974). The biological characteristics of these nuts are different from those of most seeds, and these differences present acute problems in the collection and care of these fruits. Oaks of the United States belong to a group of species called "temperate recalcitrants." They are "temperate" because they grow primarily in the temperate zone; they are "recalcitrant" because their seeds do not tolerate desiccation below a critical moisture content (approximately 20 to 35 %).

Seeds of other species, which can be desiccated to below 10 percent, are called "orthodox," which means that they behave nicely when desiccated and survive long periods of storage under proper conditions. The orthodox group contains all temperate zone conifers, and many important hardwoods, such as ash *(Fraxinus* spp.), black cherry (*Prunus serotina* Ehrh.*),* yellow-poplar *(Liriodendron tulipifera* L.), sweetgum *(Liquidambar styraciflua* L.), and sycamore *(Platanus occidentalis* L.).

The purpose of this paper is to review the crucial steps in collection and care of acorns, and to present the best current recommendations on how to collect good acorns and maintain their quality. Every step of this process is heavily influenced by the moisture relations and recalcitrant nature of acorns.

ESTIMATING ACORN CROPS

When planning acorn collections, it is usually wise to survey the crop potential in the spring in the area selected for collection. If few immature acorns are present, then plans must be changed to collect in other areas or to buy the needed acorns from a commercial dealer. Flowering in oaks is monoecious, meaning that both male and female flowers are borne on the same tree. Southern and eastern oak species usually flower before leaves appear in early spring (February to April). The male catkins are borne at the leaf axils on last year's growth **(figure 1)**, while the female flowers are borne on twigs of the current year. The two greatest dangers to the crop are late spring freezes that may kill the flowers, and heavy rains that may wash the pollen out of the air during pollination. Collectors should be aware of these conditions, as the mere presence of flowers on the trees will mean nothing if freezes or heavy rains occur at critical times.

Figure 1–Catkins on cherrybark (*Q. pagoda* Raf.) oak in March, indicating a potentially good crop year.

White and red oak species differ in their flowering and fruiting habit. White oak acorns mature in one year (the same year as flowering). Red oak acorns require two years to mature, and branches in late spring will display small 1-year-old acorns and the much smaller current year's acorns that will mature in about another 18 months **(figure 2)**. The first inspection of trees to determine the potential crop should be in late spring when all acorns that will mature that year are easy to see **(figures 2 & 3)**. Until they start to grow in size (usually in early July in the mid-South), most of the acorns will look good from the outside. As good acorns rapidly increase in size, however, aborted acorns or acorns that have been destroyed by insects will not grow. The pericarps of many will turn dark and are readily visible **(figure 3)**.

Figure 2–First- and second-year acorns on cherrybark oak in June. The second-year acorns (A) have not yet started their final year's growth, while the tiny pairs of one-year acorns (B) are seen on the ends of the limb.

Figure 3–Immature white oak (*Q. alba* L.) acorns in July. The lower acorn has started its growth spurt, while the small one above it has not. Its dark color also indicates abortion or insect damage.

In checking potential collection trees, one should be aware that limbs on the southern and western exposures of open-grown trees will usually have the greatest numbers of acorns. These limbs will receive more sunlight during the day, which stimulates flowering and helps the spread of pollen to the female flowers. In closely spaced trees in closed stands, almost all acorns will be borne on the limbs of the upper crowns and will hard to see. Total acorn crop yield will be smaller on most of these trees because of their smaller crowns. These spring counts are early estimates only, however, and a later count should be made in August or September when acorns approach full size. Look for branches loaded with acorns, as in **(figure 4).** There are no standard (or secret) ways of counting acorns to evaluate the crop; just be sure to look at potential acorn-bearing limbs on all four sides of the trees, if possible. Limbs such as the one in **figure 4** would certainly be the sign of an excellent acorn crop.

The total number of acorns per tree will vary greatly. In poor crop years only a few hundred may be present at maturity, and many of these may be ruined by insects. In poor crop years a higher percentage of the acorns will have insect damage than in good crop years. It is simple mathematics; fewer acorns for the insects to feed on! In good crop years mature trees can have anywhere from 2,000 to 30,000 acorns each. The higher numbers will be found only on large open-grown trees with full crown development (such as trees in pastures, parks, or seed orchards).

Figure 4–An excellent acorn crop on willow oak (*Q. phellos* L.).

If a good acorn crop is in place, final preparations can begin. Permission to collect on the land of others is always a must, even though it may be in public places. For example, acorns are typically numerous on trees in parks, cemeteries, schoolyards, and churchyards, but permission should be obtained here also.

MATURITY INDICES

Acorns should be collected when they are fully mature and not before. Unlike multi-seeded fruits, such as pine or yellow-poplar, single-seeded fruits generally will not complete maturation after separation from the tree. The best maturity indices for acorns are (Bonner and Vozzo 1987):

(1) Color of the pericarp.
(2) Ease of separation of acorns from cups.
(3) Cup scar color.
(4) Cotyledon color.

(1) In red oaks the pericarps should have lost their green color and be primarily dark brown or black before collection. **(figure 5)**. An occasional exception to this rule can be made for southern red *(Q. falcata* Michx.) and cherrybark oaks. Individual trees of these species may produce mature acorns with a greenish tint to their pericarps. In white oaks brown and black are also good pericarp colors that indicate maturity, but again there are exceptions. Acorns from certain trees of white and swamp chestnut *(Q. michauxii* Nutt.) oaks may be fully mature when pericarps are still yellow or even a mottled yellow and green **(figure 6)**.

Figure 5–Dark pericarps that signify maturity for acorns of cherrybark, water, and willow oaks.

Figure 6–Acorns of white oaks that are mottled in color, yet already mature.

These color changes are related to moisture loss with maturation. In Mississippi, white oak acorn moisture peaks at about 65 percent in early September, then drops to between 50 and 55 percent at maturity (Bonner 1976). With acorn moisture this high, a warm, wet October may lead to germination of acorns on the tree (called vivipary). This is a common occurence with live oak (*Q. virginiana* Mill.) along the Gulf coast, and it will sometimes occur with other species **(figure 7)**. Water oak *(Q. nigra* L.) acorns in the same region exhibit their maximum moisture content in August (65 to 70 percent), which then decreases to 35 or 40 percent at maturity (Bonner 1974c).

Figure 7-- Vivipary in chinkapin oak (*Q. muehlenbergii* Engelm.) in Oktibbeha Co. Mississippi following warm, rainy weather in October.

(2) When acorns are mature, their cups come away cleanly with only slight pressure. If attempts to remove the cups cause them to break apart and leave pieces attached to the acorn, then the acorns are not yet mature **(figure 8)**. This is a simple test to carry out when collecting from branches. Overcup oak *(Q. lyrata* Walt.) is an exception to this rule, as these acorns are disseminated with their enclosing cups attached **(figure9)**. The cup tissue is full of small air spaces, which apparently allow the acorns to float and be spread by moving water.

Figure 8–If cups slip off whole easily (left), acorns are probably mature, even if pericarp color is not ideal. If cups adhere to the acorn and break when removal is attempted (right), the acorns are not yet mature or may be diseased.

Figure 9–Overcup oak acorns with their cups that enclose the acorns and remain on the acorns when they fall from the trees.

(3) In red oaks, the cup scars on mature acorns are "bright" in color **(figure 10)**. On acorns of southern red and cherrybark oaks the scars may be bright pink or orange when first exposed. If cup scars are dark on freshly fallen acorns, they are probably no good. The dark colors usually indicate insect or disease damage and the onset of deterioration. The bright colors fade within a few days of cup loss, however, so many good acorns collected from the ground may not show these bright colors. Under these conditions the cup scars will be sort of "off-white" or ivory, but not dark. This index is most useful in checking maturity of acorns still attached to trees.

Figure10–Cup scars on acorns that have just fallen. Those on the left are "bright", indicating good acorns. Those on the right were dark when they fell and are probably ungerminable.

(4) The last test for maturity is to examine a cross-section of acorn for cotyledon color. Collectors should always carry a pair of hand shears in the field to cut acorns in half and check the embryo and cotyledons. Species with naturally high fat contents, such as water oak, should have dark yellow to orange cotyledons **(figure 11)**. A pale yellow or white cotyledon in these species indicates immaturity. Species with low fat content, such as Shumard oak *(Q. shumardii* Buckl.) and most white oaks, should have creamy white or light yellow cotyledons **(figures 12 & 13)**. Some of the smaller white oak acorns, such as post oak (*Q.* stellata Wangenh.) can have yellow cotyledon color similar to some of the small red oaks. Immature coloration in these acorns is almost the same as that of mature acorns. The higher the fat content, the deeper the orange color of the cotyledons. Mature overcup oak acorns are 50 percent carbohydrate and less than 1 percent fat (Bonner 1974a), and have almost white cotyledons. Cutting acorns in half also provides an opportunity to assess insect damage in the field **(figure 13)**. If insect larvae are found in more than 25 percent of the acorns, then collection crews should realize that additional acorns may be needed to meet prescribed goals.

Figure 11–Cross-section of red oak acorns, which exhibit good cotyledon colors (left to right; water, willow, cherrybark, and Shumard oaks).

Figure 12–Cross-section of white oak acorns which exhibit good cotyledon color. From left to right: post, chinkapin (*Q. muehlenbergii* Engelm.), overcup, white, and swamp chestnut oaks.

Figure 13–Longitudinal cuts of white oak acorns that show damage from insect larvae. The acorn on the left will not germinate, because the embryonic axis has been destroyed. The acorn on the right has only slight damage on the side, and should germinate.

Every now and then a deep freeze occurs in the South before acorn collection is complete (usually late November), and acorns on the ground are killed. A deep layer of leaves may protect them, but survival usually depends on how cold it gets and how long it stays below the freezing point. Acorns can survive for years at 2 or 3 degrees below freezing (as we know from storage tests), but short periods at much lower temperatures will be fatal. Frozen acorns turn black in color, but this may not occur until several weeks after they have been collected. Collectors should be aware of this potential problem, however, and be sure to cut samples of acorns that are being collected after periods of sub-freezing temperatures to look for signs of freeze damage.

When the same trees are collected from year after year, dates of acorn maturity should be recorded. There will be variation, of course, but maturity dates will hardly ever vary more than 2 weeks in the South. Acorn maturity will occur on some limbs before others on individual trees, but the order of ripening usually remains the same. Acorns on lower limbs also seem to mature before those on limbs in the upper crown, and this difference should be considered when checking for maturity of the acorn crop.

No one index of maturity is best for all species, locations, or individual trees. Cups will slip from acorns on some trees before pericarps reach the ideal color. Cotyledon color is often as indicated above before acorns fall cleanly from their cups. Common sense and experience should guide each collector's judgment.

COLLECTION

Although most acorns are collected from the ground after they have fallen naturally from the trees, collection of mature acorns directly from limbs will produce the highest quality of seeds. Collectors must be aware of the maturity indices as described in the previous section, of course, and there must be easy access to the crowns. If climbers or mechanical lifts are required to get to the acorn-bearing limbs, then this approach will be too expensive for general collections.

Collection from tops of downed trees in logging operations is the best (and cheapest) way to collect by hand from limbs. If acorns are mature, and they separate from the caps easily, large amounts can be collected quickly **(figure 14)**. If they are at peak maturity, the shock of the top hitting the ground may shake most of them loose. When this occurs, one can just push aside the limbs and scoop up handfuls from the ground underneath the fallen tops. If the acorns are not quite mature when the trees are felled, few will be shaken loose. If maturity would have been reached within about 5 to 7 days, many acorns will mature in the tops and can be collected for up to a week or so later. Excessively hot and dry weather will shorten this “window” for collection, as the acorns will dry too quickly. Conversely, cool and moist conditions may lengthen it. As a rule of thumb, collectors should observe the leaves; when they are fully dried out, no more ripening should be expected in the logging slash.

Figure 14–Picking white oak by hand from logging tops.

Another collection strategy to get mature acorns from the crowns is to shake the trees at the proper time. In seed orchards or open-grown stands, mechanical tree shakers can be extremely effective. At the USFS northern red oak (*Q.* rubra L.) seed orchard on the Cherokee National Forest, plastic netting is placed on the ground to facilitate picking up the fallen acorns **(figure 15)**, but raking by hand will also work if the understory and litter has been removed. Netting (or other material) can also be placed on the ground to catch the acorns that fall naturally. However, prolonged exposure to predators on the netting will be a problem, as noted below.

Figure 15–Netting on the ground underneath northern red oak trees in a seed orchard on the Cherokee National Forest.

For purely economic reasons, most acorns are collected from the ground after natural dissemination. This approach is the best bet to collect fully mature acorns, **IF** they are properly cared for. Collectors should also recognize that the first 5 to 10% of the acorns that fall are usually insect-infested or diseased, and they should not be saved. When good acorns start to fall, they should be collected from the ground within just a few days after they have fallen. There are two reasons for this action. First, predator losses can be significant: deer, squirrels, turkeys, grackles, etc. Second, acorns begin to dry as soon as they hit the ground. In hot, dry conditions, some acorn quality is lost in 24 hours; by day 3 or 4, the acorns may be dead. The loss of viability can be slowed by heavy litter that will shield acorns from sunlight and low humidity, and by cool, wet weather that slows desiccation. If good rains occur every day or so, acorn viability and quality can be maintained for a week or more (if predators don't get them). Acorn moisture content cannot be emphasized too much; as little as 5% moisture loss will decrease acorn quality to some degree !

Collection from the ground is usually done by hand-raking everything together and placing it into bags or drums. If leaves are plentiful on the ground, common leaf blowers **(figure 16)** can be used to clear the area before raking.

Figure 16–Leaf blowers are handy for cleaning the ground underneath trees before raking the acorns.

POST-HARVEST CARE

Because of the recalcitrant nature of acorns, much acorn quality is often lost between collection and storage. Acorns must be kept moist to maintain good seed quality. They should be collected and transported in plastic bags or in containers that can be covered to reduce moisture loss, especially if extended travel in the back of trucks is required. Double-weave plastic bags that are commonly used for grain seeds are very good **(figure 17)**. They prevent excessive drying, yet allow adequate air circulation. Buckets and any plastic containers (such as garbage cans) are also suitable in the field, since the acorns will be in them only a few hours. The steps that are taken to inhibit moisture loss also can lead to the problem of overheating (Gosling 1989). Overheating must be avoided, especially when plastic bags are used. Acorns should be kept in the shade while awaiting transport, and during transport, trucks should be parked in the shade when not moving. If the weather is warm, dry, and/or windy, spray the acorns with water. These are small things, but they can help maintain seed quality. In our experience, a loss of 5 percent moisture can be tolerated, but additional desiccation can lower acorn quality. If acorns are dried too much before and during collection and transport, moisture can usually be replaced by immersing the acorns in water at room or cold-storage temperature (Gosling 1989). This must be done the same day as collection. Immersion is, in most cases, a good practice, and it leads logically to cleaning, the next step in acorn care. When collecting in very dry conditions, one should always hold some acorns up to one's ear and shake them. If they "rattle", they are very dry and in danger of losing viability. The rattle noise is caused by the shrinkage of the cotyledons away from the interior of the pericarp.

Figure 17-- A double-weave plastic bag can be used in field collections. The same type of bag is also very good as a storage container.

CLEANING

As soon as possible after collection, all acorns should be immersed in water **(figure 18)**. This procedure serves two functions. First, it allows removal of leaves, cups, other trash, and insect-damaged acorns that float, Sound, healthy acorns typically sink in water. The exception to this rule is overcup oak, whose acorns always float with their large cups full of air spaces (see **figure 12**). Second, immersion helps maintain that all-important high seed moisture.

Figure 18–Flotation of acorns cleans them and removes trash and empty acorns.

If conditions are extremely dry when acorns are collected from the ground, many good acorns will float initially. Under such conditions, acorns should be kept in the water for up to 24 hours to elevate their moisture contents and allow sound acorns to sink. Acorns collected from wet conditions should separate easily at initial floating. Sometimes acorns will go halfway, neither floating nor completely sinking. These acorns are usually damaged by insects, but are too heavy to float on the surface. They should usually be discarded. But remember that samples of "floaters" and "sinkers" should always be cut to determine the effectiveness of flotation to remove bad acorns.

After flotation and removal of trash, the water should be drained away prior to storage. Insect control measures can be taken at this time if absolutely necessary. The two common methods of control are immersion in hot water (120 °F) for 40 minutes, and fumigation with methyl bromide or other recommended chemicals (Olson 1974). Both of these methods present considerable risk to acorns, and the best alternative may be to do nothing. Most infested acorns will be removed in flotation. The larvae do not attack intact acorns during storage, so infestation does not increase. Damage is further decreased when acorns are put into cold storage. The temperature change encourages larvae to emerge from the acorns to pupate, and they die in the bottom of the container. Additional larval emergence can be encouraged by moving the acorns from cold storage to room temperatures and back again. Larval feeding must destroy the embryonic axis to prevent germination, so damage solely to cotyledon tissue does not prevent germination and development of a normal seedling. More details of insect damage in acorns can be found in (NE-220) and (NE-492).

If acorns are to be sized, the separations should be done at this time. Not all nurserymen size acorns, but increasing use of mechanical planting, both in nurseries and in direct seeding, is now leading to a wider adoption of the practice. Furthermore, there is an increasing body of evidence that suggests that seedlings grown from the smallest acorns never perform as well as seedlings grown from larger acorns (see below).

Several options are available for sizing. Round-hole screens from air-screen cleaners may be used, both machine size, and hand size as seen in **figure 19**. Screens of various sizes are available from Seedburo Equipment Company, 1022 West Jackson Blvd., Chicago, IL 60607-2990, 800-284-5779. Large quantities of acorns may require other options. A large flat screen cleaner/sizer manufactured by SouthPine, Inc., P.O. Box 530127, Birmingham, AL 35253, 205-879-1099, is used successfully in several nurseries **(figure 20).** Some seed companies and nurseries use pecan sizers to size their acorn collections. Possible sources of these machines are Southern Nut'n Tree, 1-800-527-1825, and Savage Equipment Co., 580-795-3394. Many nurseries and seed dealers have constructed their own sizers, and all seem equally effective. Sizing can have advantages in nurseries through its effect on seedling uniformity. A positive correlation between acorn size and seedling size (height or leaf area) has been reported for northern red oak (Farmer 1980), English oak (*Q. robur* L.), and durmast oak (*Q. petraea* (Mattushka) Liablein). (Kleinscbmit and Svalba 1979).

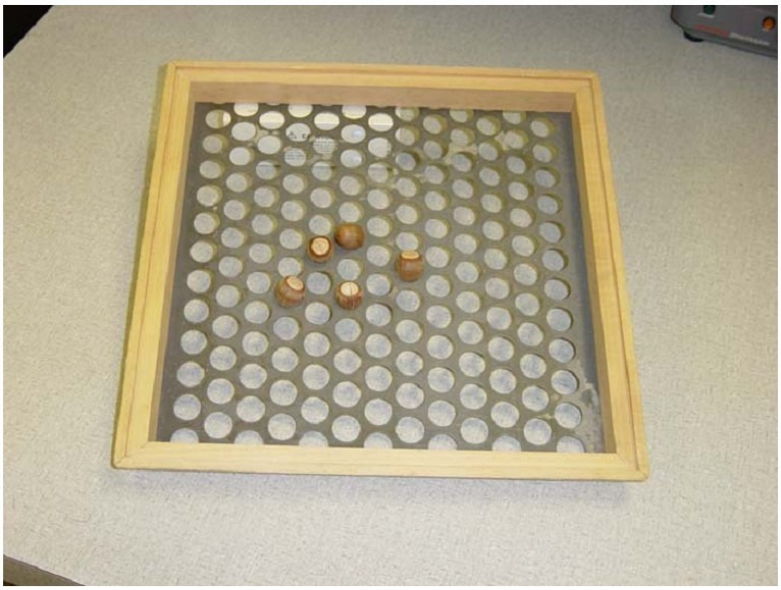

Figure 19–Round-hole cleaning screens can be used for sizing acorn lots.

Figure 20--The SouthPine Model-156 Flat Screen Cleaner/sizer.
It employs up to 5 screens to make as many as 6 size seperations.

After cleaning and sizing the acorns, a few samples should be weighed and counted to determine the number of seeds per pound (or per kg). By doing this, a good estimate can be obtained of the number of sound acorns collected. There is a great deal of variation within a species, but the following averages can be used for rough counts. The values are seeds/lb, with seeds/kg in ( ):

black oak--245 (540
cherrybark--310 (690)
chestnut oak--100 (220)
chinkapin oak--395 (870)
laurel oak--560 (1235)
live oak--350 (775)
northern red oak--105 (235)
Nuttall oak--100 (220)
overcup oak--120 (265)
pin oak--220 (475)
post oak--(380 (840)
scarlet oak--235 (520)
Shumard oak--100 (220)
southern red oak--540 (1190)
swamp chestnut (cow) oak--55 (125)
water oak--290 (640)
white oak--100 (220)
willow oak--380 (835)

STORAGE

Most seed managers do not like to store acorns over long periods, because their size requires large refrigerated storage space and because viability declines each year. Acorns of most red oaks can be stored for 3 years without critical losses in viability (Bonner 1973), while most white oaks can be stored only 6 months without complete loss of viability. One solution to the problem is to plant acorns in the fall immediately after collection and avoid storage. For some nurseries and conditions, this option is a good one for next year's crop. Short-term storage under good conditions between collection and sowing is essential to maintain good acorn quality, however, and many managers would like to store extra acorns for use 1 or 2 years later. Since good storage practices for both purposes require the same facilities and procedures, the recommendations are the same.

Acorns of red oak species should be stored with their moisture contents at 30 percent or higher in temperatures near, but above, freezing (34 to 40 °F). Air tight storage is lethal, so containers must allow some gas exchange with the atmosphere while maintaining high acorn moisture levels (Bonner 1973). Polyethylene bags with a wall thickness of 4 to 10 mils (1 to 2.5 mm) are good for small samples **(figure 21)**. For large quantities of acorns, storage can be in double-weave plastic bags **(figure 17)**, drums, cans, or boxes with polyethylene bag liners **(figure 22)**. Container tops and liners should not be completely closed; this will allow sufficient gas exchange. If water collects in the bottoms of storage containers, it should be drained from acorns intended for storage longer than over winter.

Figure 21–Self-sealing poly freezer bags are good for storage of small samples.

Figure 22–Acorns can be stored in many different containers if they are lined with plastic bags.

With proper care, many southern red oaks should maintain good viability for at least 3 years **(table 1)**. We have bad good success in our laboratory with water, cherrybark, and Nuttall *oaks (Q. nuttallii* Palmer), but less success with Shumard and willow oaks. Similar methods were used by Farmer (1975) for successful storage of northern red and scarlet *(Q. coccinea* Muenchh.) oaks, and by Suszka and Tylkowski (1982) for northern red oak in Poland.

Table 1—Germination and moisture contents of cherrybark oak acorns stored in polyethylene bags at 3 °C and 8 °C[1]

Original moisture content and storage period	Germination		Final moisture content	
	3 °C	8 °C	3 °C	8 °C
	---------- *Percent* ----------			
24 percent moisture				
6 months	80	76	27	28
18 months	9	0	30	34
30 months	25	24	32	33
31 percent moisture				
6 months	99	99	34	34
18 months	99	96	35	35
30 months	81	71	36	36
33 percent moisture				
6 months	100	98	34	32
18 months	93	95	31	36
30 months	94	34	37	40

[1] Bonner (1973).

With few exceptions, white oak acorns cannot be stored longer than over winter (4 to 6 months) without complete loss of viability. For over-winter storage, the same methods outlined for red oak storage should generally be used. Thinner polyethylene (1.75 mil, or 0.45 mm) or cloth bags may be advantageous for white oaks because their respiratory activity is faster and requires more oxygen (Rink and Williams 1984). Schroeder and Walker (1987) reported excellent results in storage of bur oak *(Q. macrocarpa* Michx.) for 6 months at 34 °F and 44 percent acorn moisture in sealed plastic bags. No information was given on the thickness of the bags. Any reduction in acorn moisture significantly decreased germination capacity and rate. Tests in our laboratory **(table 2)** have provided some rare successes with storing white oak species.

Table 2—Viability retention of various southern white oak acorns stored at 2 °C, high moisture content, and in polyethylene bags[1]

Species	Germination			
	Original	6 mo.	1 yr.	2 yrs.
	Percent			
Q. alba, white	90+	7.0	--	--
Q. virginiana, live	96.0	--	60.7	17.6
Q. muhlenbergii, chinkapin	91.3	--	39.0	2.0
Q. michauxii, swamp chestnut	86.1	--	65.1	2.0
Q. lyrata, overcup	--	--	95.8	--

[1] Bonner and Vozzo 1987.

Moisture content remains a crucial factor throughout storage. With acorn moisture levels above 30 percent and temperatures above freezing, respiration proceeds at a rapid rate. This process gradually decreases acorn dry weight, causing small increases in the percentage of moisture over time **(table 1)**. Schroeder and Walker (1987) found no increase in bur oak moisture content over 6 months of storage, but Gosling (1989) reported that English oak acorn moisture contents increased as much as 5 percent over 6 months in storage. The loss in dry weight is why a static state of equilibrium between internal acorn moisture and the storage atmosphere, such as we find in orthodox species, is never reached for acorns. Approximate equilibrium moisture contents have been determined for a few species **(table 3)**, but these probably change over long storage periods. Note that white oak has much higher equilibrium levels than the two red oak species. This is because starch, the major storage food in white oak, is more hygroscopic than lipid, the major storage food in red oaks.

Table 3—Equilibrium moisture contents of acorns for three southern oaks stored under two conditions of temperature and humidity[1]

Species	Storage conditions: 40-55% relative humidity 4-5 °C	Storage conditions: 95% relative humidity 4-5 °C
	Percent	
Shumard oak	13	32
Water oak	17	29
White oak	37	50

[1] Bonner and Vozzo 1987.

Between 70 and 75 percent of total acorn moisture in water and Shumard oaks is in the cotyledons and embryonic axes, while the comparable total for white oak is only 58 percent (Bonner 1974b). White oak pericarps are thicker than those of red oaks, and they retain more moisture. Cup scar vascular openings are major conduits for moisture uptake (Bonner 1968). Experiments in our laboratory on acorn desiccation have indicated that these openings comprise the key pathway for moisture loss also. As acorns dry, the proximal end of the cotyledons (just beneath the cup scar) loses moisture first. Unless the pericarp splits, as it does at radicle emergence, the embryonic axis and the cotyledon tissue surrounding it (distal end) is the last area to be desiccated.

One method tested successfully for storing Nuttall oak acorns solved the drying problem nicely. Johnson (1979) stored Nuttall acorns for 6 months in drums of water maintained at 34 to 40 °F. Similar results were obtained for water and cherrybark oak acorns in our laboratory for 5 months, but longer storage periods of 17 and 29 months led to considerable loss in viability.

Germination during storage has always been a problem for acorns **(figure 23)**, although not as great a problem as some might think. Southern white oaks have so little dormancy that they will germinate on the tree in extremely wet falls, so it is no wonder that they germinate profusely in storage. There seams to be an inverse relationship between degree of dormancy and germination in storage among red oak species. The conditions recommended for storage are the same ones normally prescribed for pretreatment (stratification) to overcome dormancy. Epicotyls usually do not appear, but radicles emerge and can grow as much as 8 inches in storage.

Figure 23–Acorns of Shumard oak that have germinated during storage.

Microorganisms kill many radicle tips in storage **(figure 24)**, and many more are broken when sowing takes place. For more information on presence of microorganisms, see (IUFRO). Secondary radicle development occurs in oaks, however, and other radicles should develop. These secondary radicles may even form sort of a multiple taproot system. Broken radicles did not adversely affect seedling production in nursery beds of cherrybark and Shumard oaks in Mississippi (Bonner 1982). Barden and Bowersox (1990) obtained similar results with northern red oak in Pennsylvania, but there were strong family differences. The common and proper response by seed managers is to do nothing to prevent this early germination. Decreasing acorn moisture slightly during storage of California black oak *(Q. kelloggii)* is reported to reduce the sprouting, yet not harm acorn quality (Tim Plumb, personal comm.). This approach should be studied for southern oaks.

Figure 24–Heavy infestation by microorganisms on white oak acorns during storage. Note that one emerged radicle (bottom center) has died back to a stub.

TESTING

In ideal situations seed collectors send samples of what they have collected to recognized seed testing facilities for germination tests. If the seeds are to be sold, buyers may require such tests from laboratories that use test procedures that are approved by the Association of Official Seed Analysts (AOSA 1993). Oak seeds are no exception, and the AOSA rules require the following procedures for acorns:

(1)–cut acorns in half in the middle and discard the bottom half; remove the pericarp from the top half and place it cut side down (epicotyl up) on moist paper wadding.

(2)–Incubate under lights at alternating temperatures of 86 °F for 16 hours (day) and 68 °F for 8 hours (night). Normal test period is 28 days.

(3)–count as germinated those acorns whose radicles emerge and grow downward to the paper and whose epicotyls show growth.

In situations where samples cannot be sent to seed testing laboratories, simple germination tests can be run by collectors following similar procedures. This is often the case when there is not enough time to get the seeds tested before they are to be planted. For these simple tests, the bottom of a shallow bowl or dish should be covered with moist paper towels (6 to 10 layers). The acorn samples should then be cut as described in the AOSA procedures above, and placed on the moist towels, cut side down. The dish should be covered with a transparent plastic wrap to maintain high humidity, with a few holes punched in it to give some aeration. The dish should be placed on a window sill or under a light source for at least 12 hours per day. If the paper towels dry out, water must be added. Germination should occur in about 2 weeks, if the acorns are good and healthy. For these informal tests, the full 28 days are seldom needed. A test dish with 20 acorns is shown in **figure 25**. For more information on testing, see (SO-306).

Figure 25–Dish with 25 excised embryos in an informal germination test.

Moisture test are critical for proper management of most tree seeds, but proper care of acorns simply entails keeping the moisture contents near maximum. Visual inspection of acorn samples is usually all that is needed to determine if acorns are too dry. If they are too dry, a good 24-hour soak in water should cure the problem. Therefore, collectors seldom need a precise measure of acorn moisture content. For those that may want to measure it anyway, the procedures are fully described in the following publication in Section II. See (SO-177).

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PRETREATMENT

White oaks are not dormant (at least not in the Southeast), so they normally need no treatment to stimulate germination. An overnight soak in water at room temperature prior to sowing day can be helpful, however, especially if the soil is dry.

Red oaks exhibit various degrees of dormancy, and some stratification (moist chilling) is required for timely germination. In most cases, however, proper storage of moist acorns will complete the stratification requirement, and additional treatment is not necessary. An overnight soak at room temperature prior to sowing is recommended, just as with white oak. If moisture levels during storage have been low for some reason, additional

stratification may be warranted. All red oak species should be soaked overnight and placed in poly bags after all moisture
on the surface of the pericarps has been drained off. They should then be placed back in storage temperatures (34 to 37
°F) for 4 to 8 weeks. The bags should be turned over once a week to prevent any pooling of excess moisture in the bags.

CONCLUSIONS

Acorns are the most difficult of all temperate zone American seeds to collect and care for properly. Most of the problems are related to the naturally high moisture content of these seeds and the need to maintain those moisture levels to maximize seed quality. Desiccation during collection and transport must be avoided; a 5 percent loss of moisture can harm acorn quality. Acorns of many species can maintain viability for up to 3 years if they are stored a few degrees above freezing with high moisture contents and some gas exchange allowed. If seed managers recognize the moisture considerations and plan for their impact, loss of acorn quality can be minimized.

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