JuglandaceaeCWalnut family

Carya Nutt.

hickory

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Growth habit, occurrence, and use. Of the dozen or so species of hickories native to the United States, 9 are valuable for timber and the food they provide for wildlife (table 1). All are deciduous trees. Pecan and its many horticultural varieties and hybrids are widely cultivated for nuts in large plantations in the southern and southwestern United States, as well as in many other countries. The first known selections were made in 1846, and many cultivars were available by the late 19th century (Madden and Malstrom 1975). Budding and grafting have been the primary means of improvement, but new provenance studies (Grauke and others 1990) and advanced research on the reproductive biology and genetics of pecan (Graves and others 1989; McCarthy and Quinn 1990; Yates and Reilly 1990; Yates and Sparks 1990) demonstrate the promise for future improvements in nut production and disease resistance. Shellbark and shagbark hickories have also been planted for nut production.

Flowering and Fruiting. Hickories are monoecious and flower in the spring (table 2). The staminate catkins develop from axils of leaves of the previous season or from inner scales of the terminal buds at the base of the current growth. The pistillate flowers appear in short spikes on peduncles terminating in shoots of the current year. Hickory fruits are ovoid, globose, or pear-shaped nuts enclosed in husks developed from the floral involucre (figure 1). Husks are green prior to maturity and then turn brown to brownish black as they ripen (Bonner and Maisenhelder 1974). The husks become dry at maturity in the fall (table 2) and split away from the nut into 4 valves along sutures. Husks of mockernut, nutmeg, shagbark, and shellbark hickories, as well as those of pecan, split to the base at maturity, usually releasing the nuts. Husks of pignut, bitternut, sand, and water hickories split only to the middle or slightly beyond and generally cling to the nuts. The nut is 4-celled at the base and 2-celled at the apex. The edible portion of the embryonic plant is mainly cotyledonary tissue (figure 2) and has a very high lipid content (Bonner 1971; Bonner 1974; Short and Epps 1976).

Collection, extraction, and storage. Hickory nuts can be collected from the ground after natural seedfall or after shaking the trees or flailing the limbs. Persistent husks may be removed by hand, by trampling, or by running the fruits through a macerator or a corn sheller. Several studies have shown that the larger nuts of pecan make larger seedlings (Adams and Thielges 1977; Herrera and Martinez 1983), so sizing of nuts may be beneficial. Shagbark and shellbark hickory trees have been known to produce 0.5 to 0.75 hl (1 2 to 2 bu) and 0.75 to 1.1 hl

(2 to 3 bu) of nuts, respectively (Bonner and Maisenhelder 1974). Good crops of all species are produced at intervals of 1 to 3 years (table 3). Some typical yield data are presented in table 4.

Storage tests with pecan and shagbark hickory have demonstrated that the hickories are orthodox in storage behavior, that is, they should be dried to low moisture contents and refrigerated. Seedlots of nuts of both species dried to below 10% moisture and stored at 3 ˚C in sealed containers retained viability well for 2 years before losing half to two-thirds of their initial viability after 4 years (Bonner 1976b). The poor results after 4 years are probably due to the high lipid levels in these seeds, which places them in the sub-orthodox storage category (Bonner 1990). There are no storage data for other species of hickory, but it is reasonable to think that they can be stored in a similar fashion.

Pregermination treatments. Hickories are generally considered to exhibit embryo dormancy, although work with pecan suggests that mechanical restriction by the shell is the reason for delayed germination in that species (van Staden and Dimalla 1976). Other research with pecan has shown that there is a clinal gradient in stratification requirement. Seedlots from southern sources are practically nondormant, whereas those from northern sources require treatment for prompt germination (Madden and Malstrom 1975). The common treatment is to stratify the nuts in a moist medium at 1 to 4 ˚C for 30 to 150 days (table 5). Stratification of imbibed nuts in plastic bags without medium is suitable for most species (Bonner and Maisenhelder 1974), and good results have been reported for pecans from southern sources by soaking the nuts at 20 ˚C for 64 hours (Goff and others 1992). There are indications that stratification should be shortened for stored nuts; this was the case in one storage test on pecan and shagbark hickory (Bonner 1976b). If cold storage facilities are not available, stratification in a pit with a covering of about 0.5 m of compost, leaves, or soil to prevent freezing will suffice. Prior to any cold stratification, nuts should be soaked in water at room temperature for 2 to 4 days with 1 or 2 water changes each day to insure full imbibition (Eliason 1965). There is evidence that germination of pecan can be increased by treatment with gibberellins (Bonner 1976a; Dimalla and van Staden 1977), but practical applications have not been developed.

Germination tests. Official testing rules for North America (AOSA 1993) prescribe testing pecan and shagbark hickory at alternating temperatures of 20 ˚C (dark) for 16 hours and 30 ˚C (light) for 8 hours on thick creped paper for 28 days. Stratification for 60 days as described above is also recommended. Adequate germination tests can also be made on stratified nuts in flats of sand, peat, or soil at the same temperature regime (table 5). Quick tests with tetrazolium salts can also be used with hickories (Eliason 1965).

Nursery practice. Either fall sowing with untreated seed or spring sowing with stratified seed may be used. Excellent results with fall sowing have been reported for shagbark hickory, but good mulching is necessary (Heit 1942). Drilling in rows 20 to 30 cm (8 to 12 in) apart and 2 to 4 cm (: to 1 2 in) deep with 20 to 26 nuts/m (6 to 8/ft) is recommended; about 100 seedlings/m^2 (10/ft^2) is a good density (Williams and Hanks 1976). Mulch should remain until germination is complete. Shading is generally not necessary, but shellbark hickory may profit from shade. Protection from rodents may be required for fall sowings.

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Table 1C*Carya*, hickory: nomenclature and occurrence

Scientific name & synonym(s)	Common name	Occurrence
***C. alba* (L.) Nutt. ex Ell.** *C. tomentosa* (Lam. ex Poir.) Nutt. *Hicoria tomentosa* (Lam. ex Poir.) Raf.	**mockernut hickory,** bullnut, white hickory, whiteheart hickory, hognut, mockernut	S New Hampshire to S Michigan, S to E Texas & N Florida
***C. aquatica* (Mich f.) Nutt.** *Hicoria aquatica* (Michx. f.) Britt.	**water hickory,** bitter pecan swamp hickory Valley to Illinois	Coastal Plain from Virginia to S Florida & E Texas; N in Mississippi
***C. cordiformis* (Wangenh.) K. Koch.** *Hicoria cordiformis* (Wagenh.) Britt.	**bitternut hickory,** bitternut, swamp hickory, pignut	New Hampshire to Minnesota, S to E Texas & Georgia
***C. glabra* (P. Mill.) Sweet** *Hicoria glabra* (Mill.) Britt. *C. microcarpa* (Nutt.) Britt.	**pignut hickory,** sweet pignut, pignut, swamp hickory	New Hampshire to NE Kansas, S to Arkansas & NW Florida
***C. illinoensis* (Wangenh.) K. Koch** *Hicoria pecan* (Marsh.) Britt. *C. oliviformis* (Michx. f.) Nutt. *C. pecan* (Marsh.) Engl & Graebn.	**pecan,** sweet pecan, nuez encarcelada	S Indiana to SE Iowa; S to Texas & E to Mississippi & W Tennessee; local to Ohio, Kentucky, & Alabama
C. laciniosa (Michx. f.) G. Don *Hicoria laciniosa* (Michx. f.) Sarg. shellbark, kingnut, bottom	**shellbark hickory,** bigleaf shagbark hickory, big Virginia; local in Louisiana,	Ohio & Mississippi Valleys; W New York to E Kansas, E to Georgia & shellbark, big shagbark hickory Alabama, & Virginia
***C. myristiciformis* (Michx. f.) Nutt.** *Hicoria myristicaeformis* (Michx. f.) Britt.	**nutmeg hickory,** bitter water hickory, swamp hickory	Mississippi W to SE Oklahoma, S to E Texas & Louisiana; also E South Carolina & central Alabama
***C. ovata* (P. Mill.) K. Koch** *Hicoria alba* Britt. p.p. *H. ovata* (P. Mill.) Britt.	**shagbark hickory,** scalybark hickory, shagbark, shellbark hickory	Maine to SE Minnesota, S to E Texas & Georgia
***C. pallida* (Ashe) Engl. & Graebn.** *Hicoria pallida* Ashe	**sand hickory,** pale hickory, pallid hickory	New Jersey & Illinois, S to Florida & SE Louisiana

Sources: Little (1979), Sargent (1965).

Table 2C*Carya,* hickory: phenology of flowering and fruiting

Species	Flowering dates	Fruit ripening dates	Seed dispersal dates
C. alba	AprBMay	SeptBOct	SeptBOct
C. aquatica	MarBMay	SeptBNov	OctBDec
C. cordiformis	AprBMay	SeptBOct	SeptBDec
C. glabra	AprBMay	SeptBOct	SeptBOct
C. illinoensis	MarBMay	SeptBOct	SeptBOct
C. laciniosa	AprBJune	SeptBNov	SeptBOct
C. myristiciformis	AprBMay	SeptBOct	SeptBOct
C. ovata	AprBJune	SeptBOct	SeptBOct
C. pallida	MarBApr	SeptBOct	SeptBOct

Source: Bonner and Maisenhelder (1976).

Table 3C*Carya*, hickory: height, seed-bearing age, seed crop frequency, and year first cultivated

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Interval between large seed crops (yrs)
C. alba	30	1766	25	2B3
C. aquatica	30	1800	20	1B2
C. cordiformis	15B30	1689	30	3B5
C. glabra	24B27	1750	30	1B2
C. illinoensis	34B43	1766	10B20	1B2
C. laciniosa	37	1800	40	1B2
C. myristiciformis	24B30	C	30	2B3
C. ovata	21B30	1911	40	1B3
C. pallida	12-30	C	C	2B3

Source: Bonner and Maisenhelder (1974).

Table 4C*Carya,* hickory: seed data

Species	Place collected	No. fruits /hl	No. fruits /bu	Wt. seeds/ vol fruit kg/hl	Wt. seeds/ vol fruit lb/bu	Cleaned seeds/weight Range /kg	Range /lb	Average /kg	Average /lb
C. alba	C	C	C	C	C	75B249	34B113	200	90
	Mississippi	5,040	1,776	57	44	71B106	32B48	79	36
C. aquatica	Mississippi	C	C	C	C	305B419	138B140	360	164
C. cordiformis	C	C	C	51	40	275B408	125B185	344	156
C. glabra	C	C	C	51	40	386B496	175B225	441	200
	Mississippi	10,100	3,552	C	C	C	C	143	65
C. illinoensis	C	C	C	C	C	121B353	55B160	220	100
	Mississippi	20,800	7,330	C	C	333B384	151B174	357	162
	Texas	C	C	C	C	C	C	311	141
C. laciniosa	C	C	C	C	C	55B77	25B35	66	30
C. myristiciformis	Mississippi & Arkansas	14,500	5,110	C	C	207B375	94B170	273	124
C. ovata	C	17,600	6,200	38B49	30B38	176B331	80B150	220	100
	Wisconsin	C	C	C	C	C	C	291	132
	Mississippi	12,100	4,264	C	C	C	C	207	94

Source: Bonner and Maisenhelder (1974).

Table 5C*Carya, hickory:* stratification period, germination test conditions, and results

Species	Cold Germination stratification period (days)	Medium	Germination test conditions: Temp. (°C) Day	Temp. (°C) Night	Duration (days)	Germination percentage: Rate (%)	Period (days)	Ave. (%)	Samples
C. tomentosa	90B150	Sand, peat soil	30	20	93	54	64	66	4
C. aquatica	30B90	Soil	27B32	21	63	76	28	92	1
C. cordiformis	90	Sand, peat soil	30	20	250	40	30	55	3
	90	soil	27	21	50	60	50	60	1
C. glabra	90B120	Sand, peat soil	30	20	30B45	C	C	85	2
C. illinoensis	30B90	Sand, peat	30	20	45B60	C	C	50	9
	30B90	Kimpak	30*	20	60	80	33	91	6
	30	Soil	32	21	35B97	C	C	75	2
C. laciniosa	90B120	Sand, peat soil	30	20	45B60	C	C	C	C
C. myristiciformis	60B120	Kimpak	30*	20	60	53	50	60	2
C. ovata	90B150	Sand, peat	30	20	45B60	75	40	80	6
	60B120	Kimpak	30*	20	60	65	35	73	2

Source: Bonner and Maisenhelder (1974).
* Daily light period was 8 hours.

Figure 1C*Carya*, hickory: nuts with husks attached and with husks removed; the size and shape of individual nuts varies greatly within species and may differ from the examples shown here, - 1.

Figure 2C*Carya ovata*, shagbark hickory: longitudinal section through thte embryo of a nut with husk removed, × 2.