FagaceaeCBeech family

Fagus L.

beech

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Growth habit, occurrence, and use. The beechesCthe genus *Betula*Cincludes 10 species of medium-sized, deciduous trees native to the temperate regions of the Northern Hemisphere (Rehder 1940). Only 1 species, American beech, is native to North America, whereas another, the European beech, has been widely planted as an ornamental in the Northeast (table 1). Some authorities have argued that there are separate northern and southern species of American beech, but this view is not widely supported (Tubbs and Houston 1990). Beeches that grow in northeastern Mexico are now classified as a variety of American beechC*F. grandifolia* var. *mexicana* (Martinez)C(Little 1965). There is some evidence of geographic races of European beech in that species= native range (Rudolf and Leak 1974). Beech wood is used for flooring, furniture, veneer, plywood, ties, charcoal, and many specialty products. The trees are highly valued for ornamental plantings, and the mast is widely utilized by numerous birds and animals (Tubbs and Houston 1990).

Flowering and fruiting. Beech flowers are monoecious. The minute male and female flowers appear in the spring when the leaves are about one-third grown (table 2). The staminate flowers occur in densely clustered, drooping heads 8 mm wide, whereas the pistillate flowers are generally paired on stout stalks about 2.5 cm long (Brown and Kirkman 1990). Flowers of European beech are quite vulnerable to late spring frosts (Matthews 1955). The fruit is a prickly bur approximately 2 cm long, which opens soon after maturity in the fall (figure 1).

Each fruit contains 2 or 3 yellowish-brown or chestnut-brown, unevenly triangular nuts, 1 to 1.5 cm long (figures 2 and 3). Times of flowering, fruiting, and seed dispersal for the 2 species are listed in table 2. Natural seed dispersal is chiefly by gravity and by animals such as rodents and blue jays (*Cyanocitta cristata*) (Johnson and Adkisson 1985; Tubbs and Houston 1990). Information on height at maturity, minimum seed-bearing age, and interval between good seed crops is shown in table 3.

Long-term studies of seed production of European beech in England show widespread variation among trees and crop years (Harmer 1994). A positive correlation between size of the seed crop and air temperature and amount of sunshine in July has also been recorded (Matthews 1955). A study in Hungary found that production of viable seeds was increased 3.5 times by fertilization of the stand with 200 kg/ha of N and 240 kg/ha of P_2O_5 (Fuhrer and Pall 1984). Predispersal destruction of seeds in Sweden by a mothC*Cydia fagiglandana* Z.Cwas found to range from 3 to 38% of the total crop, depending on crop size (Nilsson and Wastljung 1987). Studies in New

England documented higher losses in American beech from insects, rodents, and birds combined (Gruber and Leak 1992; Leak and Gruber 1993). Records of seed production by American beech have shown that there is a great amount of natural variation, but no geographic or elevational patterns (Gysel 1971; Sain and Blum 1981; Stalter 1982). Like many other species, the better producers in any particular year will usually produce good crops in other years (Grisez 1975).

Collection and extraction. Beech nuts may be raked from the ground after they have fallen or shaken from the trees onto canvas or plastic sheets after the fruits open naturally (table 2). There is some evidence that seeds of European beech caught by nets suspended above the ground have less fungal infection than seeds raked from the ground (Dubbel 1989). Closed fruits also can be picked in the fall from trees recently felled in logging operations. Seed maturity is indicated by a completely brown fruit, and care should be taken to ensure that the seeds are fully mature when collecting unopened fruits. After the fruits are stripped from the branches, they should be spread to dry in a thin layer until they open and the nuts can be shaken out. The nuts can be separated from empty fruits, leaves, and other large trash by screening. European beech seeds collected in Germany are sometimes separated from leaves, twigs, and fruit capsules with a tractor-mounted cleaning machine at the collection sites (Gottfriedsen 1991). Data on seed yields and weights are given in table 4.

In a good seed year, in France, a 150-year-old European beech high forest yielded 50 hl/ha (57 bu/ac) of seed, whereas in Germany, a beech forest yielded 900 to 1,680 kg/ha (800 to 1,500 lb/ac) of seed (Rudolf and Leak 1974).

Storage and pregermination treatments. Seeds of European beech can be stored for at least 6 years without loss of viability by drying the seeds to a moisture content of 8 to 10% at room temperature and holding them in sealed containers at temperatures from -5 to -15 ˚C (Muller and Bonnet-Masimbert 1982; Suszka 1974). Poulsen (1993) recommends that drying should be done at temperatures below 20 ˚C. This behavior would seem to put beeches into the orthodox class of storage behavior, although there is evidence that beeches fit somewhere between the orthodox and recalcitrant classes (Gosling 1991) or in the sub-orthodox class (Bonner 1990). The high lipid content of 40.7% reported for kernels of European beech (Prasad and Gulz 1989) would seem to support the sub-orthodox classification. The seeds are basically orthodox, however, and 5 years of storage is long enough for operational storage. There are no comparable data for American beech, but there are no reasons to suspect that this species cannot be treated in the same way. Beech seeds require cold stratification (prechilling) for prompt germination, and current practices with European beech have combined stratification and storage into a coordinated procedure. The first step is to determine how much stratification is needed to overcome dormancy (Suszka and Zieta 1977). Samples of fresh seeds are brought to maximum moisture content or mixed with moist sand and stored at 3 ˚C until about 10% of the seeds have started germination (radicles are visible). This period is assumed to be the amount of time required to overcome dormancy in that particular lot. The remainder of the seeds are adjusted to a moisture content of 28 to 30% and prechilled in plastic containers (without media) at 4 ˚C for this amount of time, plus 2 more weeks. At this level of moisture, dormancy is overcome, but germination does not begin (Muller and Bonnet-Masimbert 1983). The seeds are then brought to room temperature, or no higher than 20 ˚C (Poulsen 1993), without heating, dried to a moisture content of 8%, and stored in sealed containers at -5 ˚C (Muller and Bonnet-Masimbert 1989). The effect of stratification is retained, and germination is prompt

when the seeds are sown. Moisture level is the key to successful stratification. Treatment without media can lead to excessive seed moisture; it should not exceed 30% (Muller and Bonnet-Masimbert 1983).

Long-term storage of beech seeds for germplasm conservation may be possible with cryopreservation techniques. Intact seeds may not survive the temperatures of liquid nitrogen (-196 °C) (Ahuja 1986), but excised embryos have survived the same conditions for at least 24 hours (Jorgensen 1990).

Germination testing. The prescribed testing method for European beech is to germinate stratified seeds on the top of moist blotters at 3 to 5 °C. Test duration varies according to degree of dormancy (see above), but may run up to 24 weeks, which includes 140 days of stratification at the same 3 to 5 °C (Suszka 1975). Some laboratories also test stratified beech seed at the common alternating regime of 30 °C (day) and 20 °C (night) with acceptable results (table 5). Because of the lengthy tests, viability estimation by tetrazolium staining is recommended as an alternate method (ISTA 1993). Both tetrazolium and indigo carmine staining (Suszka 1991) are commonly used in Europe. North American testing rules (AOSA 1993) do not include either of these beech species, but the same methods should work for both. Germination is epigeal (figure 4).

Nursery practice. Beech seed can be sown in the fall as soon after collection as possible, or stratified seed can be sown in the spring. In the stratification/storage procedure described earlier for European beech, seeds can be removed from storage and planted at any time in the spring without additional treatment. This procedure eliminates the uncertainty over when to start stratification in time for spring sowing and is favored by nurserymen in Europe (Gosling 1991). Sowing density should be 700 viable seeds/m^2 (65/ft^2) for European beech, which, on the average, should produce about 325 seedlings/m^2 (30/ft^2) (Aldhous 1972). Seeds should be covered with 12 mm (2 in) of soil. Fall-sown beds should be mulched until midsummer and given special protection against rodents (Rudolf and Leak 1974). Some seedbeds may require half-shade until past mid-summer. Vegetative propagation by cuttings is very difficult, but some successes have been reported for stem cuttings taken in late summer. Grafting is more common for ornamental selections (Dirr and Heuser 1987).

Literature Cited

Ahuja MR. 1986. Short note: storage of forest tree germplasm in liquid nitrogen (-196 °C). Silvae Genetica 35: 249B251.

Aldhous JR. 1972. Nursery practice. Bull. 43. London: Forestry Commission. 184 p.

AOSA [Association of Official Seed Analysts]. 1993. Rules for testing seeds. Journal of Seed Technology 16(3): 1B113.

Bonner FT. 1990. Storage of seeds: potential and limitations for germplasm conservation. Forest Ecology and Management 35: 35B43.

Brown CL, Kirkman LK. 1990. Trees of Georgia and adjacent states. Portland, OR: Timber Press. 292 p.

Dirr MA, Heuser CW Jr. 1987. The reference manual of woody plant propagation: from seed to tissue culture. Athens, GA: Varsity Press. 239 p.

Dubbel V. 1989. Die Bedeutung des Bodenkontaktes für die Qualität des Buchensaatgutes. Forst

und Holz 44(19): 512B516 [Seed Abstracts 15(4): 1261; 1992].
Fuhrer E Jr, Pall M. 1984. Aspekte der Auswahl von Buchensaatgutbestanden: Möglichkeiten der Erhöhung des Samenertrages durch Düngung. Zentralblatt für das Gesamte Forstwesen 101:33B48 [Seed Abstracts 7: 1923; 1984].
Gosling PG. 1991. Beechnut storage: a review and practical interpretation of the scientific literature. Forestry 64: 51B59.
Gottfriedsen D. 1991. Bucheckernernte mit SilvaSat. Forst und Holz 46(9): 256B257 [Seed Abstracts 17(3): 942; 1994].
Grisez TJ. 1975. Flowering and seed production in seven hardwood species. Res. Pap. NE-315. Upper Darby, PA: USDA Forest Service, Northeastern Forest Experiment Station. 8 p.
Gruber RE, Leak WB. 1992. Seed fall in an old-growth northern hardwood forest. Res. Pap. NE-663. Upper Darby, PA: USDA Forest Service, Northeastern Forest Experiment Station. 11 p.
Gysel LW. 1971. A 10-year analysis of beechnut production and use in Michigan. Journal of Wildlife Management 35: 516B519.
Harmer R. 1994. Natural regeneration of broadleaved trees in Britain: 2. Seed production and predation. Forestry 67: 275B286.
ISTA [International Seed Testing Association]. 1993. International rules for seed testing. Rules 1993. Seed Science & Technology 21 (Suppl.): 1B259.
Johnson WC, Adkisson CS. 1985. Dispersal of beech nuts by blue jays in fragmented landscapes. American Midland Naturalist 113(2): 319B324.
Jorgensen J. 1990. Conservation of valuable gene resources by cryopreservation in some forest tree species. Journal of Plant Physiology 136: 373B376.
Leak WB, Gruber RE. 1993. Six-year beechnut productiion in New Hampshire. Res. Pap. NE-677. Upper Darby, PA: USDA Forest Service, Northeastern Forest Experiment Station. 6 p.
Little EL, Jr. 1965. Mexican beech, a variety of *Fagus grandifolia*. Castanea 30: 167B170.
Little EL, Jr. 1979. Checklist of United States trees (native and naturalized). Agric. Handbk. 541. Washington, DC: USDA Forest Service. 375 p.
Matthews JD. 1955. The influence of weather on the frequency of beech mast years in England. Forestry 28: 107B116.
Muller C, Bonnet-Masimbert M. 1982. Long term storage of beechnuts: results of large scale trials. In: Wang BSP, Pitel JA, eds. Proceedings, International Symposium on Forest Seed Storage; 1980 September 23B27; Chalk River, ON. Ottawa: Environment Canada, Canadian Forestry Service,: 178B183.
Muller C, Bonnet-Masimbert M. 1983. Amélioration de la germination des faines (*Fagus sylvatica* par prétraitement en présence de polyéthylène glycol. Annales des Sciences Forestieres 40: 157B164.
Muller C, Bonnet-Masimbert M. 1989. Breaking dormancy before storage: an improvement to processing of beechnuts (*Fagus sylvatica* L.). Seed Science & Technology 17: 15B26.
Nilsson SG, Wastljung U. 1987. Seed predation and cross-pollination in mast-seeding beech (*Fagus sylvatica*) patches. Ecology 68: 260B265.
Poulsen KM. 1993. Predicting the storage life of beech nuts. Seed Science & Technology 21: 327B337.
Prasad RBN, Gulz PG. 1989. Composition of lipids of beech (*Fagus sylvatica* L.) seed oil.

Zeitschrift für Naturforschung [Section C, Biosciences] 44: 735B738.
Rehder A. 1940. Manual of cultivated trees and shrubs hardy in North America. 2nd ed. New York: Macmillan. 996 p.
Rudolf PO, Leak WB. 1974. *Fagus* L., beech. In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: USDA Forest Service: 401B405.
Sain RE, Blum KE, 1981. Seedling production in the high-elevation beech (*Fagus grandifolia* Ehrh.) forests of the Great Smoky Mountains National Park. Castanea 46: 217B224.
Stalter R. 1982. Production of viable seed by the American beech (*Fagus grandifolia*). Bulletin of the Torrey Botanical Club 109: 542B544.
Suszka B. 1974. Storage of beech (*Fagus sylvatica* L.) seeds for up to 5 winters. Arboretum Kornickie 19: 105B128.
Suszka B. 1975. Cold storage of already after-ripened beech (*Fagus sylvatica* L.). Arboretum Kornickie 20: 299B315.
Suszka B. 1991. The indigo carmine test. In: Gordon AG, Gosling P, Wang BSP, eds. Tree and shrub seed handbook. Zurich: ISTA: 10,1B10,9.
Suszka B, Zieta L. 1977. A new presowing treatment for cold-stored beech (*Fagus silvatica* L.) seed. Arboretum Kornickie 22: 237B255.
Tubbs CH, Houston DR. 1990. *Fagus grandifolia* Ehrh., American beech. In: Burns RM, Honkala BH, tech. coords. Silvics of North America. Volume 2, Hardwoods. Agric. Handbk. 654. Washington, DC: USDA Forest Service: 325B332.

Table 1C*Fagus,* beech: nomenclature and occurrence

Scientific name	Common name	Occurrence
***F. grandifolia* Ehrh.**	**American beech,** beech	Nova Scotia to S Ontario & N Michigan, S to N Florida & E Texas
***F. sylvatica* L.**	**European beech**	Europe; planted in NE US

Source: Little (1979).

Table 2C*Fagus,* beech: phenology of flowering and fruiting

Species	Flowering dates	Fruit ripening dates	Seed dispersal dates
F. grandifolia	MarchBMay	SeptBNov	SeptBNov (after frost)
*F. sylvatica**	AprBMay	SeptBOct	OctBNov (after frost)

Sources: Brown and Kirkman (1990), Rudolf and Leak (1974), Tubbs and Houston (1990).

* Dates are similar for western Europe and the northeastern United States.

Table 3C*Fagus,* beech: height, seed-bearing age, and seed crop frequency

Species	Height at maturity (m)	Year first cultivated	Minimum seed-bearing age (yrs)	Interval between large seed crops	
				Time (yrs)	Location
F. grandifolia	21B37	1800	40	2B3	C
		4B5	Wisconsin		
F. sylvatica	20B30	Long ago	40B80*	5B8	Mtn areas
			9B12	Great Britain	
				3B10	C
				15B20	C

Source: Rudolf and Leak (1974).
* 40 to 50 years for open-grown trees and 60 to 80 years for trees in stands.

Table 4C*Fagus,* beech: seed yield data

Species	Fruit wt/vol kg/hl	Fruit wt/vol lb/bu	Seed wt/fruit vol kg/hl	Seed wt/fruit vol Lb/bu	Cleaned seeds/wt Range /kg	Cleaned seeds/wt Range /lb	Cleaned seeds/wt Average /kg	Cleaned seeds/wt Average /lb	Samples
F. grandifolia	C	C	12	9	2,850B5,110	1,290B2,320	3,500	1,600	10
F. sylvatica									
fresh fruits	50B53	39B41	C	C	4,000B6,200	1,800B2,800	4,630	2,100	24+
air-dried fruits	39B45	30B35	C	C	C	C	C	C	C

Source: Rudolf and Leak (1974).

Table 5C*Fagus,* beech: germination test conditions and results

Species	Cold stratification (days)	Test conditions: Medium	Test conditions: Temp (°C) Day	Test conditions: Temp (°C) Night	Germination rate: Amount %	Germination rate: Period (days)	Germination (%)
F. grandifolia	90	Sand	30	20	84 47	85	C
F. sylvatica	42	Sand, paper	30	20	C	C	81
F. sylvatica							
fresh seeds	140	Sand + peat	1	1	56 120	100	C
stored seeds	150	Sand + peat	5	5	60 110	100	C

Source: Rudolf and Leak (1974).