

Wild G. American Ginseng

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Photo by Joseph G Strauch Jr

ABSTRACT

American ginseng (*Panax quinquefolius* L. [Araliaceae]), a native plant species of North American eastern woodlands, is highly sought for its medicinal value. The long-lived perennial herb reaches a maximum height of about 50 cm (20 in) and annually grows a determinate shoot from a short underground rhizome atop a fleshy taproot. Ginseng harvesters remove the root, which kills the plant. Commercial harvesting of wild ginseng plants has occurred since the 1700s. Continued pressure for wild harvested roots potentially threatens to diminish the size and number of populations in many states in the US, and the species faces possible extirpation in others. The Nature Conservancy's Natural Heritage ranking of the species globally changed in 2000 from "common" to "rare/common." Fewer than half the US states and Canadian provinces rank the species "apparently secure." Seeds are the sole means of reproduction and relatively few seeds are produced before plants are vulnerable to harvest. The trend may be to harvest younger plants as ginseng populations are depleted of larger plants by harvesting and as number and size of populations decline. Balancing commercial demands with actions necessary to preserve the species should dictate our behavior. Fortunately, we know more about the biology of ginseng than most species that are in peril in portions of their historic ranges. Effective management and monitoring programs must incorporate this knowledge to ensure that ginseng will be maintained as a viable species and continue to be a product of our native forests.

KEY WORDS: American ginseng, CITES, conservation, exported species, habitat characteristics, life cycle, Natural Heritage, *Panax quinquefolius*, wild harvest

NOMENCLATURE: (North American plants) Gleason and Cronquist (1991); (species of *Panax*) Wen and Zimmer (1996); (Insecta Hymenoptera) Muesebeck and others (1951); (Insecta Diptera Syrphidae) Metcalf (1913)

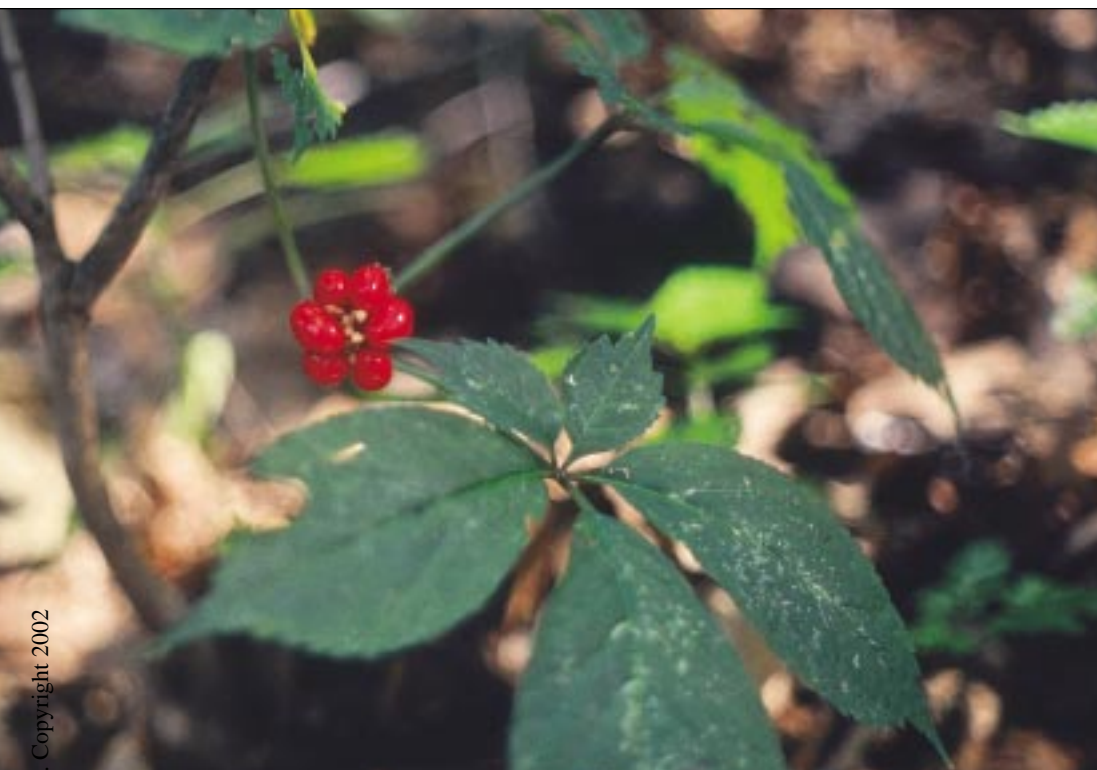


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Figure 1 • American ginseng (*Panax quinquefolius* L.) plant bearing mature red fruits in late summer in central Illinois, US.

es a maximum height of about 50 cm (20 in). A determinate shoot grows annually from a short underground rhizome that emerges from a fleshy taproot. Ginseng harvesters dig this taproot, killing the plant. At maturity, ginseng has 3 to 5 palmately compound leaves, each with 3 to 5 leaflets, arising from atop a short aerial stem. Individual leaves are commonly called “prongs.” Persons who harvest (diggers) and who buy and sell ginseng (dealers) often describe the size of a plant by referring to the number of leaves or “prongs” they bear, such as a “3-pronger,” a plant with 3 leaves. Diggers and dealers also refer to the leaflets as leaves. In late spring to midsummer, the inflorescence develops from the terminus of the aerial stem. By autumn, a tight cluster of bright red berries each about 0.5 to 1 cm (0.2 to 0.4 in) wide, contain 1 to 3 seeds (Figure 1). The aerial stem dies back sometime from August to October.

GEOGRAPHIC DISTRIBUTION AND HABITAT CHARACTERISTICS

American ginseng occurs from southern Quebec and Ontario west to South Dakota and south to Georgia and Oklahoma (Gleason and Cronquist 1991; NatureServe 2001; Environment Canada 2001; USDA 2001). Ginseng is found in moderately to very shady hardwood forests with cool microclimates throughout most of its geographic range (Fountain 1982; Anderson and others 1993; Anderson 1996; Gagnon 1999). It is physiologically adapted to low light levels, reaching light saturation (the intensity at which an increase in light does not increase photosynthesis) at levels as low as 10% of full sunlight (Proctor 1980). Recommendations for light intensities to maximize growth of American and Korean ginseng (*Panax ginseng* C.A. Meyer [Araliaceae]) vary from about 8% to 30% of full sunlight (Park 1980; Proctor 1980). For Korean ginseng, a species with similar habitats to American ginseng, minimum, optimum, and maximum light intensities for photosynthesis were less than 1%, 8%, and 30%, respectively (Kim 1964). At moderately high light intensities, ginseng experiences leaf chlorosis (Gagnon 1999), early senescence, and depressed growth. Extensive tree harvest and cattle grazing can negatively affect ginseng,

America is mad about ginseng. Drug stores and health food stores stock numerous herbal products with ginseng prominently displayed on the labels. Television advertisements abound tempting viewers to believe that taking ginseng will result in a more glamorous, more vigorous, longer, richer, and sexier life. Even checkout lines at the grocery stores prominently display, next to the gum, candy and *The National Enquirer*, attractive single dose “emergency” packets of ginseng. Simultaneously, small woodlands owners are urged to consider the profitability of planting American ginseng on their forested property or to keep the land forested for watershed and habitat protection for wild ginseng plants (Nadeau and others 1999; Bolgiano 2000). Programs to conserve wild populations are on the desks of numerous public and private conservation organizations. Canada lists it as Endangered and has a species recovery plan (Environment Canada 2001). The USDA Forest Service-Eastern Region lists American ginseng in its Sensitive Species List (USFWS 2000).

In this article, we present an overview of information about the biology of wild American ginseng, and issues related to its harvest and conservation. We leave to others the examination of methods of cultivation and human health values of ginseng roots (for example, Duke 1989).

American ginseng, *Panax quinquefolius* L. [Araliaceae], a long-lived perennial forest herb, reach-

because both tend to open the forest canopy, and cattle eat ginseng (Ambrose 1990; Anderson and others 1993). Selective tree cutting, however, may not negatively affect ginseng because most of the tree canopy remains intact (Anderson 1996). Ginseng is usually found on slopes that range from 10% to about 40%, but it can occur on slopes as steep as 60% (Fountain 1982; Anderson and others 1984, 1993; Anderson 1996). Some protection from direct solar radiation characterizes most of the sites ginseng occupies, and most populations are found on north-facing slopes (Fountain 1982; Anderson and others 1984, 1993; Duke 1989; Anderson 1996). In narrow ravines with a north-south orientation, ginseng tends to occur on lower slope positions of the typically hot and dry west-facing slopes (Anderson 1996) where the plant remains in topographic shade of the opposing east-facing slope during a portion of the afternoon. Similar selection of protected habitats occurs in the mountainous regions of the eastern portion of its US range, where ginseng occurs in sheltered coves (Bourne 2000). Although ginseng grows under a wide range of soil moisture conditions (Anderson 1996), its best development occurs on moist sites; we have not seen the plant on poorly drained sites.

Ginseng tolerates a wide variety of soil texture, fertility, and pH conditions. It grows in soils containing from 9 to 184 kg/ha (8 to 164 lb/ac) of phosphorus, 476 to 7224 kg/ha (425 to 6450 lb/ac) of calcium, 184 to 358 kg/ha (164 to 320 lb/ac) of potassium, and 112 to 1400 kg/ha (100 to 1250 lb/ac) of magnesium and ranging in pH from 4.4 to 7.5 (Fountain 1982; Konsler and Shelton 1990; Anderson and others 1984, 1993; Anderson 1996). The plant forms arbuscular mycorrhizal associations (Soe and Anderson 1990; Whitbread and others 1996). This generally mutualistic relationship may be important in allowing it to grow on sites with low levels of inorganic nutrients. In the mycorrhizal association, the fungus invades the plant root system and produces external hyphae, which function as a supplemental root system increasing the availability of inorganic nutrients to the plant, especially those of low mobility in the soil such as phosphorus.

Ginseng's growth is undoubtedly influenced by soil fertility, however, we are unaware

of studies that compare the growth response of ginseng to varied soil nutrient conditions under natural field conditions.

Although ginseng diggers use jack-in-the-pulpit (*Arisaema triphyllum* (L.) Schott. [Araceae]), bloodroot (*Sanguinaria canadensis* L. [Papaveraceae]), and mayapple (*Podophyllum peltatum* L. [Berberidaceae]) as indicator species, no plant species are consistent indicators of ginseng habitat. Tree species commonly associated with ginseng vary across ginseng's geographic range. In Wisconsin, Illinois, and Arkansas they include white and red oaks (*Quercus alba* L. [Fagaceae] and *Q. rubra* L.), sugar maple (*Acer saccharum* Marshall. [Aceraceae]), American beech (*Fagus grandifolium* Ehrh. [Fagaceae]), mockernut hickory (*Carya tomentosa* (Poir.) Nutt. [Juglandaceae]), and white ash (*Fraxinus americana* L. [Oleaceae]) (Fountain 1986; Anderson and others 1984, 1993; Anderson 1996). These trees are common on dry mesic to mesic sites. Herbaceous understory species often associated with ginseng in the same 3-state region include jack-in-the-pulpit, cluster-sanicle (*Sanicula gregaria* Bickn. [Apiaceae]), lopseed (*Phyrma leptostachya* L. [Verbenaceae]), maidenhair fern (*Adiantum pedatum* L. [Adiantaceae]), false Solomon seal (*Smilacina racemosa* L. [Liliaceae]), and rattlesnake-fern (*Botrychium virginianum* (L.) Swartz. [Ophioglossaceae]). In Kentucky, bloodroot, wild ginger (*Asarum canadensis* L. [Aristolochiaceae]), Solomon's seal (*Polygonatum biflorum* (Walter) Elliot [Liliaceae]), mayapple, goldenseal (*Hydrastis canadensis* L. [Ranunculaceae]), and jack-in-the-pulpit were the most common associates of ginseng (Duke 1989).

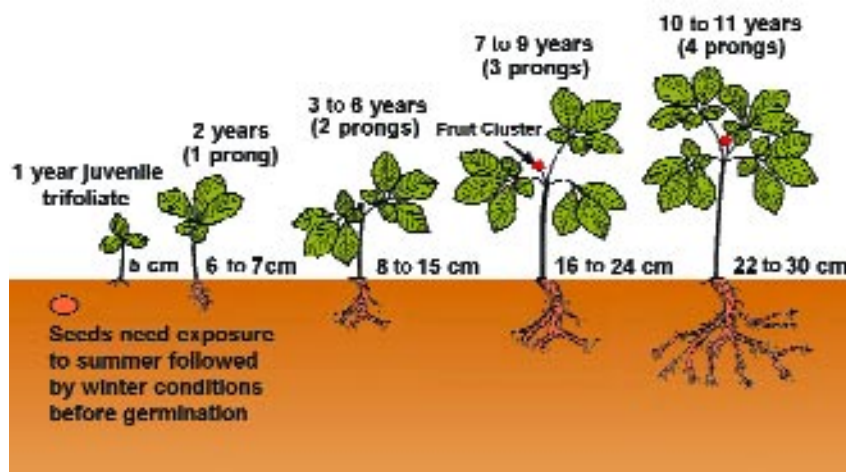


Figure 2 • Generalized life cycle of ginseng showing development and growth from the 1-y juvenile stage to 10- to 11-y-old plants bearing 4 leaves (prongs) each with 5 leaflets and a cluster of fruits.

COMMERCIAL HARVESTING OF AMERICAN GINSENG

Historical Harvest

American ginseng is almost identical in appearance to the Asian species that has been used in traditional Chinese medicine for millennia, and it was assumed to have similar medicinal properties. Consequently, American ginseng has been exported for medicinal purposes to Asian markets since its discovery in the 1700s by French explorers and Jesuit missionaries in Quebec. Roots were sent by shiploads to Chinese merchants for lucrative prices that rivaled the fur trade (Schorger 1969).

In Canada, ginseng exploitation followed the pattern of fur harvesting (Gagnon 1999). Fur trading companies bought roots as well as furs to meet European and Asian demand. The potential for profit provided incentive for widespread harvesting regardless of the stage of growth or time of year. In 1748, demand for ginseng was so great that “all the Indians near Montreal were searching for the root so that the farmers could not hire, as usual, a single Indian to assist in harvesting their crops.” By the early 19th century, the plant was rarely found in Quebec forests (Schorger 1969; Carlson 1986).

Collection of the root followed settlement westward into Canada and the US. By 1750, the plant was discovered in New England, and the US ginseng trade mirrored that occurring in Canada (Schorger 1969). Harvest was especially important in New York, Massachusetts, Vermont, and the Appalachian region (Nash 1898). In 1773, a cargo of 242,550 kg (534,730 lb) of dried ginseng was sent to China on a single ship (Williams 1957). By the mid-1800s, ginseng was exported from states as far west as Wisconsin (Nash 1898), Indiana, and Illinois (Duiz 1874). In 1805, the botanist Andre Michaux reported that ginseng was a desirable product from Kentucky that was easily transported overland to Philadelphia, the center of commerce and exportation of ginseng. Misfortune struck a famous Kentuckian involved in ginseng trade however. Daniel Boone bought ginseng for transport to Philadelphia, but more than 13,610 kg (30,000 lb) was lost when a single boat overturned on the Ohio River (Bakeless 1939). The root was in great demand in the 1820s and 1830s, and many people were said to have made their living by digging it. Near Crawfordsville, Indiana, Mr James Kimler reported seeing a factory for drying ginseng and preparing it for use (Duiz 1874). Anecdotal reports from southern Wisconsin reported wagonloads of ginseng harvested at first, then dwindling later, presumably due to over harvesting (Schorger 1969). After about 1895, attempts were made to cultivate ginseng, possibly due to declining harvests of wild roots (Schorger 1969; Carlson 1986; Anderson 1996). It is difficult to imag-

ine any wild plant capable of growing fast enough to withstand this extent of annual losses (Gagnon 1999). Wild populations were being harvested to near-extirpation.

Current Harvest

Contemporary records of wild ginseng harvest are based on purchases by licensed dealers for export. In 1999, the US harvested 29,360 kg (64,725 lb) of dried American ginseng roots of wild or wild-simulated plants. Wild-simulated plants develop from hand seeding or planting of seedlings in forests. Additionally, wild-simulated plants may undergo fertilization, experience reduced competition as a result of understory thinning, and receive protection from herbivores (Gagnon 1999). Thus, they grow in similar conditions as native populations of ginseng, but they receive varied levels of husbandry and may have come from a non-local source of seeds or juvenile roots. Ginseng plants grown under cultivation have smoother and less branched roots than wild grown or wild-simulated plants, which bring a lower price (US\$ 13 to \$26/kg versus \$275 to \$1100 [\$6 to \$12/lb versus \$125 to \$500]) on the commercial market. After harvest, wild and wild-simulated roots appear similar. According to TRAFFIC North America (Robbins 1998), about two-thirds of the American ginseng harvest is exported to China, primarily through Hong Kong, with the remainder going to domestic markets.

Harvest of wild or wild-simulated roots in 1999 was only about one-half of the 55,110 kg (121,498 lb) average annual harvest for the period from 1990 to 1999 (USFWS 2000). Variation in annual harvest amounts may be affected by several factors. From a biological perspective, the most important consideration is summarized by the US Fish and Wildlife Service. This federal agency regulates the export of wild ginseng roots and it reports anecdotal information from dealers and harvesters in many states that suggest ginseng populations are becoming small or hard to find (USFWS 2000). Another factor relates to price. If the price per pound falls appreciably, diggers may gather fewer roots, or may store them until prices rise. Also, during good economic times, traditional ginseng harvesters may earn more income than usual from regular employment, reducing their incentive to harvest roots. Cultivated roots are exempted from regulation under international treaty obligations.

SYSTEMATICS AND RELATED SPECIES

There are 2 North American species of *Panax*: American ginseng (*P. quinquefolius* also called *P. quinquefolium*) and dwarf ginseng (*P. trifolius* L.). *Panax* is one of more than 100 genera of flowering plants with representatives in eastern Asia and eastern North America in disjunct distributions. Ten other *Panax* species occur in woodland habitats in Asia, from the

Himalayas to the Pacific coast (Wen and Zimmer 1996). Based on DNA analysis (Wen and Zimmer 1996) and pollen ultrastructure (Wen and Nowicke 1999), all 12 species of the genus *Panax* have a single origin, that is, the genus is monophyletic. The 2 North American species are more distantly related to each other than to Asian species. American ginseng is most closely related to *P. ginseng*, Chinese or Korean ginseng and *P. japonicus* C.A. Meyer, but *P. trifolius*, dwarf ginseng, the other North American species, is the most distantly related to all other species of *Panax* (Wen and Zimmer 1996).

Both scientific names, *P. quinquefolius* and *P. quinquefolium*, are used for American ginseng in recent academic literature. Linnaeus named *Panax quinquefolium* (Graham 1966; Reveal 1991), deriving the generic name *Panax* from Greek terms meaning “cure-all,” for its reputed medicinal use in China. According to Wen (2001), taxonomic specialist on *Panax*, gender rules for the Latin name dictate that the correct form is *Panax quinquefolius*. The Convention on International Trade in Endangered Species (CITES) lists the species as *Panax quinquefolius*.

GENERALIZED LIFE CYCLE

Distinctive phases characterize seasonal and developmental growth patterns of ginseng (Figure 2). Mature clusters of red fruits appear during late summer or early fall as leaves begin to senesce. Bright red fruit highlighted against the fall yellow-colored leaves provides an identifier readily used by diggers. Although the bright red color of ginseng fruit suggests bird dispersal, most fruits are found within a meter (3.3 ft) or less of mature plants. Populations of ginseng tend to form clusters of a few to several hundred plants, which are separated by distances of several hundred meters or more without intervening plants, further suggesting that ginseng seeds normally are not dispersed long distances from their origin.

Seeds do not germinate during the first growing season after dispersal because they must experience warm followed by cool temperatures for the tiny embryo in the seed to overcome dormancy and grow. This morphophysiological dormancy (Baskin and Baskin 1998) is broken after about 20 mo, and seeds germinate during spring of the second growing season following ripening. There is no long-term storage of seeds in the soil (Anderson and others 1984, 1993; Charron and Gagnon 1991).

Juvenile plants have a single leaf bearing 3 leaflets and may retain the same appearance their second year. For casual observers, ginseng seedlings may be difficult to distinguish from other species, but close observation reveals a reliable characteristic to make the identification. Small unbranched hairs on the upper side of the leaflets along the major veins help to

distinguish ginseng seedlings from other understory plants, such as black snake root (*Sanicula marilandica* L. [Apiaceae]), cluster-sanicle, and hornwort (*Cryptotaenia canadensis* (L.) DC. [Apiaceae]), whose seedlings have similar trifoliate leaves. Older ginseng plants also have unbranched hairs along major veins. Additionally, crushed fresh leaves of black snake root, cluster-sanicle, and hornwort have a somewhat aromatic odor absent in ginseng.

The herbaceous aboveground growth dies back after a single growing season and a new herbaceous stem appears the next year. The

shoot reaches its maximum size relatively early in summer and does not add leaves or leaflets during the same summer. As plants grow older, they usually add leaflets annually, up to five per leaf, followed by adding more leaves. Some young plants progress from bearing a single leaf with 3 leaflets, to supporting 2 leaves, each with 3 leaflets. Growth rate varies among individuals so plants with the same number of leaves and leaflets may be close but not identical in age.

Detailed anatomical and morphological studies of ginseng rhizome development reveal how it can be used in aging plants (Anderson and others 1993). In the first year after germination, the portion of embryo axis below the cotyledons (the hypocotyl) does not elongate. So, the first true leaf and root meet at the seed leaves node (cotyledonary node), the root collar. Buds form in the axil of each cotyledon.

The 2 buds are of different sizes and the smaller remains dormant. The next growing season, the larger bud forms a short rhizome and a single determinate shoot, which are terminated by a single leaf. The shoot also forms 2 buds at its base where it joins the rhizome. The larger bud again gives rise to a short rhizome and a terminal shoot in the subsequent growing season (Figure 3).

Each year's growth adds to the rhizome length through addition of a new basal internode. A dormant bud at the cotyledonary node evidences the first year's growth, where the rhizome and the root collar

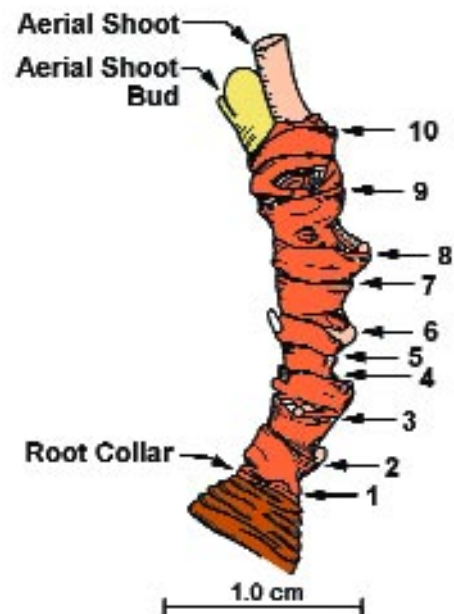


Figure 3 • Rhizome of a 10-y-old ginseng plant showing its attachment to the root crown and the aerial shoot bud and the attachment point of the shoot. The numbers indicate annual growth features that can be used to age the rhizome as described in the text.

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join. A circle of bud scales and a persistent dormant bud mark the growth in subsequent years. A shelf-like aerial shoot abscission scar is adjacent to each dormant bud. Each aerial shoot rotates nearly 90° clockwise or counterclockwise on the shoot axis from the previous one. Ginseng roots can be aged accurately by using the connection of the rhizome and root collar to mark the first year's growth and a circle of bud scale scars and a dormant bud to determine each subsequent year's growth (Anderson and others 1984, 1993; Lewis 1987). Thus, the aging method described here is based on the fundamental architecture of the plant. Over 50 roots of cultivated (of known age) and wild plants from 1 to 20 y were examined while developing the aging procedure (Anderson and others 1984; Armstrong 2001). Plants generally grow taller and produce more leaves and leaflets each year (Figure 2). Likewise, older plants produce larger taproots, and size of the aerial stem is a general indicator of root size. Several researchers have reported significant positive correlation between plant size (for example, stem height, number of leaves or leaflets) and root weight (Lewis 1978; Anderson and others 1984, 1993). Differences among sites and

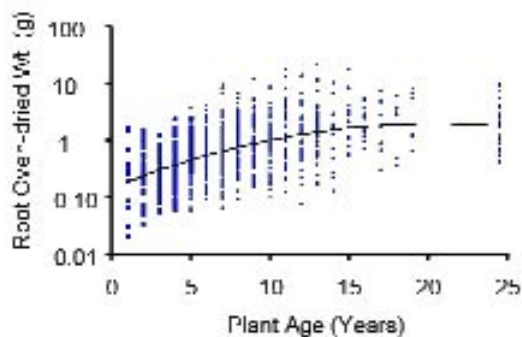


Figure 4 • Root weight (\log_{10} scale) regressed against 1-y age classes for 950 American ginseng roots obtained from ginseng dealers in 11 US states. Roots 20 y and older were combined into a single class.

growing conditions, however, result in variation in expected age-size relationships (Carpenter and Cottam 1982; Lewis and Zenger 1982, 1983; Anderson and others 1984, 1993; Anderson 1996). Additionally, plants occasionally emerge in the spring with fewer leaves or leaflets than the previous

year, especially if they suffer herbivory damage (Charron and Gagnon 1991; authors' personal observation). White-tailed deer browse ginseng, often consuming most of the aboveground portions of the plant or sometimes the entire inflorescence of green fruit (authors' personal observation). Moreover, systematic observation of wild populations indicates that plants may be dormant and not visible for a season or more, then reappear (Drees 2000).

GROWTH RATES AND AGE STRUCTURE OF POPULATIONS

Two- and three-leaf plants often constitute the largest number of mature (non-seedling) plants in wild pop-

ulations, while 4-leaf plants are less common. Plants with 5+ leaves are extremely rare, partly because of their desirability for harvest. Seedling numbers in populations vary widely as a function of site, year-to-year variation in annual fruit production, and growing season rainfall (Charron and Gagnon 1991; Anderson 1996). Seedling survival rates depend on site and climatic variation (Lewis and Zenger 1983; Anderson and others 1984, 1993; Charron and Gagnon 1991; Anderson 1996), but after reaching the 2-leaf size, plant death from natural causes decreases. For example, in Canadian populations, annual seedling mortality varied from 8% to 79% (Charron and Gagnon 1991). By comparison, for 325 Wisconsin plants, annual mortality was 46% for seedlings and single-leaf plants combined, 12% for 2-leaf plants, 6% for 3-leaf plants, and 5% for 4-leaf plants (Anderson 1996).

The life span of ginseng is estimated to be in excess of 50+ y (Lewis and Zenger 1982) to an unlikely 400 (Heffern 1976). Based on our experience with a single population of field-grown plants, where at least some harvesting of roots occurred, relatively few plants are older than 10 y. We estimate the upper age to be about 25 to 30 y (Anderson and others 1993). On a site protected from harvesting, the upper age ranges around 27 to 30 y (Anderson 1996).

POLLINATION BIOLOGY AND FRUIT AND SEED PRODUCTION

Flowering occurs from mid spring to mid to late summer across the northern and midwestern portion of the species range in the US and extends from about 5 to as many as 10 wk at a single location (Lewis and Zenger 1983; Anderson and others 1984, 1993; Schlessman 1985). Artificially established populations complete flowering in about 3 to 4 wk (Lewis and Zenger 1983; Catling and Spicer 1995; Schluter and Punja 2000). In Illinois, flowering extends from early May through mid August, with earlier flowering in central and southern areas and later in the northern area (Anderson and others 1984, 1993). American ginseng potentially can set seeds from cross- and self-pollination. Mating system experiments found no difference between seed production of self- and cross-pollinated flowers (Schlessman 1985) and no difference between pollinator-excluded treatments versus open-pollinated controls (Schlessman 1985) or increased fruit production for pollinator-excluded treatments (Schluter and Punja 2000). However, maturation of anthers and release of pollen before stigmas are exerted increases the probability of outcrossings (Lewis and Zenger 1983; Schlessman 1985). Nevertheless, stigmas are most receptive to pollen tube germination before and after anther dehiscence, providing only weak temporal separation of stigmatic receptivity and anther

dehiscence (Schlessman 1985). A few generalist pollinators have been reported visiting natural populations, including halictid bees of the genus *Dialictus* (Duke 1980), *Dialictus zephyrus* Smith (Hymenoptera: Halictidae) and *Evyllaes* sp. (Lewis and Zenger 1983), and syrphid flies: *Mesogramma geminata* Say (Diptera: Syrphidae) [formerly *Toxomerus geminatus* Say as listed in Duke (1980)], *Mesographa boscii* Macq. (Diptera: Syrphidae), and *Melanostoma mellinum* L. (Diptera: Syrphidae) (Schlessman 1985). Insect visitation only occasionally happens. Schlessman (1985) reported rarely seeing more than 3 visitors per 30 min.

As suggested earlier, seeds are probably gravity dispersed, although the bright red fruit appears attractive for bird dispersal (Lewis and Zenger 1982; Anderson and others 1984, 1993; Schlessman 1985). Even occasional long-distance dispersal by birds could markedly affect outcrossing rates, differentiation among populations, and the founding of new ones. Haphazard dispersal by ginseng harvesters also occurs, as ginseng harvesters are encouraged to plant seeds a short distance from recently harvested plants (USFWS 2000).

As fruits mature, pedicels enlarge to support the fruit and change in color from green to red. Small undeveloped fruits, possibly unfertilized or aborted, remain attached to the inflorescence late in the season, sometimes until the peduncle falls, and their pedicels remain generally slender and green. The number of mature fruits an inflorescence produced can be determined by counting mature fruits and enlarged reddish pedicels. Fruits contain 1 to 3 seeds with each carpel producing a single seed. The number of expanded carpels, and hence seeds, may be observed readily from the fruit exterior by counting the number of fruit lobes. Stigma remnants remain attached to fruit but may not reliably indicate the number of seeds in the fruit, because some ovules are unfertilized or aborted. The fleshy red outer pericarp surrounds a tough seed coat and a leathery endocarp (Schlessman 1985; Thompson 1987).

Wild ginseng grows slowly and may not flower for 4 y. Fruit production increases with age and size: 2-leaf plants have 0 to 2 fruits and seeds per plant, and 3-leaf plants have 4 to 6 fruits and 5 seeds. Four-leaf plants produced the most seeds: 12 to 30 fruits and mostly 2 seeds per fruit (Carpenter and Cottam 1982; Lewis and Zenger 1982; Anderson and others 1984, 1993; Schlessman 1985; Charron and Gagnon 1991; Anderson 1996).

EFFECT OF HARVESTING ON WILD POPULATIONS

The US Fish and Wildlife Service regulates commercial harvest and sale of ginseng, but harvest regulations are developed by individual states involved in

export of roots. The level of collecting is monitored by counting number of roots in 0.11 to 0.23 kg (0.25 to 0.50 lb) samples of air-dried roots obtained from dealers (USFWS 2000). The assumption is that if the number of roots per unit weight increases, smaller plants are being harvested, signaling an increased intensity of collecting. Presumably as population size declines, diggers are forced to collect smaller roots to maintain income. A strong age-weight relationship would suggest that as harvested roots become smaller, younger plants are being harvested, and the size of the wild population is being reduced.

To test the assumption of this method to correlate root weight and plant age, we examined a sample of 950 commercially harvested wild ginseng roots from 11 states. The small range in age of roots from individual states resulted in no significant pattern between age and root weight for individual states. However, \log_{10} oven-dry root weight regressed against 1-y age classes for all states combined showed that root weight increased linearly up to about 15 y, thereafter the increase in root weight with age decreased. Data were best fit with a second degree polynomial regression ($P < 0.01$, $df = 948$, $R^2 = 0.26$) that accounted for 26% of the variation in root weight (Figure 4). Root mass has been shown to increase with inflorescence removal in American ginseng (Proctor and others 1999). Therefore, the decline in increasing root weight with age after 15 y could be due to older plants investing more resources into fruit production and less into root mass.

The 950 harvested roots ranged from 1 to 39 y old. Mean age for the sample was 8.2 y (mode = 7 y). There was a tendency for harvested roots from southern states to have younger mean ages than those harvested from northern states. Additionally, there was a linear increase in root weight with an increase in latitude ($Y = 0.071X - 2.784$, where $Y = \log_{10}$ oven-dried root weight, and $X =$ state midpoint latitude, $P < 0.01$, $df = 948$, $R^2 = 0.19$) for the 11 states. These results suggest that harvest pressure might be greater in the southern states than in the northern ones. The linear regression, however, accounted for only 19% of the variation in root weights and other factors could be responsible for the increasing root weight with latitude, including environmental or genetic factors. Nevertheless, these latitudinal trends in root weight may warrant further investigation. Additional evidence for more intensive collection in the southern portion of the species range is provided by McGraw (2001) who examined size of 915 ginseng herbarium specimens that were collected over 186 y. Overall, plants declined in size over time for same-aged plants, with most of the change occurring since 1900. Plants collected from midwestern, Appalachian, and southern states declined in stature the most, while northern populations showed little change. In the early

1800s, northern specimens were generally smaller than southern, Appalachian, and midwest specimens but in the late 1900s the opposite was true. Possible causes of the trend toward smaller plants are unknown. Ginseng, however, has experienced over 2 centuries of harvesting, and if humans routinely collect the largest plants, slower-growing individuals may be left to repopulate a site. In addition, diggers may have eradicated plants from optimal sites (McGraw 2001).

A shift in age structure to younger plants results in a reduction in fruit production and signals a potential decline in population size. For example, in Illinois, plants older than 7 y (3-leaf plants) produced 68% of all fruits (69.3 fruits/0.05 ha) on sites protected from harvesting and 58% of fruits (18.9 fruits/0.05 ha) on unprotected (that is, harvested) sites (Anderson and others 1984, 1993). Harvesting of ginseng reduces population size and, generally, small population size reduces genetic diversity with a concomitant reduction in adaptive variation necessary for a population or species to survive changing or variable environments (Barrett and Kohn 1991; Huenneke 1991). The problem of reduced genetic diversity in small populations is compounded by the reproductive biology of American ginseng. The mixed mating system, including both self- and cross-fertilization, low frequency of pollinator visitations, and predominantly local seed dispersal would be expected to contribute to inbreeding and, thus, reduced levels of genetic diversity. Moreover, a recent study has shown that pollinator activity and seed set are positively related to population size in experimentally established populations of ginseng (Hackney and McGraw 2001).

Harvesting may also result in the creation of small isolated populations rather than the formerly more continuous populations that promote gene exchange. Estimated size of unharvested populations needed to avoid extinction for at least 100 y with more than 95% probability was 172 plants, including at least 55 plants with more than 2 leaves (Nantel and others 1996). They calculated that harvesting more than 4.4 of these large plants annually would reduce the growth rate below a sustainable level. Most harvesters would not harvest so few plants from this large a population (Nantel and others 1996). In addition, most wild populations are smaller than the minimum estimated size to avoid extirpation, and thus should be considered at great risk of local extinction. If few or no plants are left undisturbed in a population after harvest, the population may be too small to recover.

USING BIOLOGICAL CHARACTERISTICS TO MAKE CULTIVATION DECISIONS

Numerous publications are readily available on how to grow ginseng, however, additional insight from the species biology may assist in decision making. In gen-

eral, cultivation of ginseng in beds much like a garden, under artificial shade, provides optimal nutrients, moisture, and shade for more rapid growth than occurs under natural forest conditions. Nevertheless, some biological problems remain, including fungal pathogens (Parke and Shotwell 1989; Punja 1997).

Disease problems in cultivation are probably due to plant density and monoculture, although we do not know studies that test this directly. All diseases, including fungi, spread more rapidly when available hosts, such as ginseng, are spatially close together. When forest-grown ginseng is planted in suitable forests, the biologically conservative decision would be to space plants far apart to reduce disease problems. Other forest understory plants interspersed among them probably have a role in preventing spread of disease that may be more important than their competition for resources.

Genetic diversity of *P. quinquefolius* has been assessed in cultivated and wild populations. Cultivated ginseng from Ontario had relatively high genetic diversity (Bai and others 1997). Genetic diversity among several native populations in Pennsylvania, Tennessee, and Wisconsin, however, was greater than in all cultivated populations sampled in Wisconsin, the southeastern Appalachian region of US, and Canada (Boehm and others 1999). Genetic diversity of cultivated ginseng in the US and Canada was a subset of that found in Wisconsin wild populations, consistent with the historical evidence that all cultivated *P. quinquefolius* were derived from several Wisconsin wild populations (Schorger 1969).

Enhancing genetic diversity of a local population is important biologically, especially if the goal is to establish a self-maintaining population. Therefore, saving seeds from only a few plants to start a new population will inevitably lead to a group of plants that are closely related, perhaps mostly siblings. Irrespective of the number of seeds planted, the result may be a few genetic lineages of many genetically similar individuals and, perhaps, few genes suited to the new site. The best way to propagate a new population from wild seed would be to collect 1 or 2 fruits from a large number of individuals, and from numerous local populations.

If seeds are harvested from a particularly large, productive plant found in the wild, the expectation may be that these seeds are superior stock for establishing other populations. Ecology explains, however, why results may not meet expectations. The wild parent may be large because of the growing conditions on the site, not because of its superior genetic condition. Through chance avoidance of being harvested, it may simply be old enough to produce more seeds than the collector was used to seeing. If so, the seeds planted in a different site may produce smaller, more slow-growing plants than expected because the site is

(S3)" in 16 states (Michigan, Delaware, Maine, New Hampshire, New Jersey, Connecticut, Georgia, Illinois, Indiana, Iowa, Maryland, Massachusetts, Minnesota, Mississippi, South Carolina, Vermont); and "apparently secure (S4)" in 11 states (Alabama, Arkansas, Kentucky, Missouri, New York, North Carolina, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin). Some states have a mixed ranking, indicating some uncertainty about the status of the species. In addition, the species is reported (SR) in Ohio and Kansas, but no conservation rank is applied (NatureServe 2001). Not all of these states permit harvest of wild roots (USFWS 2000). In Canada, ginseng is listed as "imperiled (S2)" in Quebec and "vulnerable to extirpation (S3)" in Ontario (Figure 5). It has been reported from Manitoba ("SR") and may be an exotic "(SE?)" in Saskatchewan (NatureServe 2001), although Environment Canada (2001) lists ginseng as only occurring in southern Ontario and southwestern Quebec. The general trend to give the species a lower rank indicating greater rarity than in previous decades is likely a result of harvest pressure. US Fish and Wildlife Service reports that in the late 1970s, about 30% of exported roots were of wild origin, but in 1999 only 3.5% of roots exported were wild-harvested, with the remaining percent being cultivated (USFWS 2000).

Overall, the future for North American ginseng is not secure without continued vigilance. Pressure for wild-harvested roots potentially threatens to diminish the size of wild populations in many states in the US, and the species faces possible extirpation in others. The perceived rarity of ginseng has elicited uneven responses from management entities. Canada has developed a Species Recovery Plan (Environment Canada 2001) and the US Forest Service has reduced the number of collecting permits issued for several national forests (Robbins 1999; USFWS 2000). Additionally, several US agencies have joined representatives from industry, academia, American Indian nations, and environmental organizations to form the Medicinal Plant Working Group to improve conservation of ginseng and other wild medicinal species (Lyke 2000).

We hope this article will encourage those who regulate the harvest and export of ginseng, and those involved in the commercial trade of the species, to think about what needs to be accomplished to maintain ginseng as a viable species from our native forests. We know more about the biology of ginseng than other species that are in peril in portions of their historic ranges. Balancing commercial demands with preservation actions should dictate our behavior. The future of wild ginseng depends heavily on responsible behavior by wild harvesters and dealers, in addition to adequate and effective monitoring and management programs.

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