Plant Guide

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GOLDENSEAL
Hydrastis canadensis L.
plant symbol = HYCA

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Alternate Names
orangeroo, yellow-puccoon, fard inolien, hydrastis du Canada, racirie jaunisse, sceau d'or, kanadische Orangewurz, hidrastis, raíz de oro

Key Web Sites
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The following topics are addressed in the publication, Cultivating the increasingly popular medicinal plant, goldenseal: Review and update by Adrianne Sinclair and Paul M. Catling, which is reproduced below:
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Cultivating the increasingly popular medicinal plant, goldenseal: Review and update

Adrianne Sinclair and Paul M. Catling

Abstract. *Interest in the cultivation of goldenseal is increasing and this may have benefits for agriculture, human health, and conservation. To enable a better understanding of growing conditions, cultivation methods reported in the literature were reviewed, 21 natural goldenseal populations in the northern portion of its natural range in North America were described and analyzed in terms of population size and health, and 15 successful growers were interviewed on requirements for optimal cultivation. Growing conditions in the wild were compared to those reported in the cultivation literature. Summary of data from natural populations suggests goldenseal grows best in mixed hardwood forests, under 60-65% shade, in moist sandy loam soils high in organic matter, with pH 5.7 to 6.3. Similarly, review of the literature suggests that goldenseal grows best in moist, well-drained loams high in organic matter, with pH 5.5 to 6.5. Reported shade requirements vary but 47-80% shade is considered optimal. Growing conditions reported by growers were also consistent with the cultivation literature and similar to conditions of wild populations. Although optimal growing conditions are similar to those for many crops, goldenseal is relatively robust and can grow well in a variety of conditions including wet, predominantly sandy or clay soils with pH as low as 4.8 and as high as 7.8. Cultivation can utilize a ginseng crop infrastructure and goldenseal has been recommended as a rotation crop for ginseng.*

Commercial production of goldenseal is potentially advantageous because (1) it is an environmentally friendly crop; (2) it has been grown successfully far outside its natural range, is easy to grow, and is considered potentially profitable; and (3) it is relatively inexpensive, having low energy, land area, and fertilization requirements. Development of a sustainable crop may contribute to the protection of native wild gennplasm, which can provide valuable material for crop improvement.

Key words: ginseng, natural resource conservation, plant ecology, propagation, soil characteristics, sustainable agriculture, wild germplasm

Introduction

Goldenseal *(Hydrastis canadensis* L.) is a North American woodland herb with a yellow perennial rhizome. A new stem grows each year about 30 cm high. The leaves are large (up to 30 cm wide), usually with five lobes. A single white flower, a mass of stamens with no petals, is produced from late April to May, depending on latitude and altitude, followed in July by a bright red berry with 10 to 30 black seeds. The natural range of the plant extends from southern New England west through the extreme southwestern portion of southern Ontario, to southern Wisconsin, and south to Arkansas and northern Georgia.

Goldenseal is highly valued for its rhizome and roots that contain medicinal alkaloids (Small and Catling, 1999). The roots have antibiotic properties, suppressing certain bacteria, protozoans, and fungi, and are used to treat AIDS and other severe chronic diseases, and digestive disorders, and to enhance the immune system (Davis and Bit, 1998). Commercial formulations prepared from the plant are widely used to treat colds and nasal congestion, as well as certain infections and parasites (Small and Calling, 1999).

Increasing popularity

Previously available only in specialty health and natural foods stores, goldenseal and other medicinal herbs became part of the general marketplace during the 1990s, and since then the demand has been increasing dramatically (Foster, 2000). Between 1991 and 1996, the wholesale value of goldenseal in the U.S. increased by as much as 600% (Robbins, 1996). Since 1994 goldenseal has been one of the top six best-selling medicinal herbs in the U.S. (Robbins, 1996; Small and Catling, 1999), and remains so today (Foster, 2000). Between 1995 and 1997, the medicinal plant market as a whole, as well as demand for goldenseal, experienced in excess of a 30% growth rate (USFWS, 1997). Goldenseal is also available in numerous drug products (Small and Catling, 1999) and in a wide array of herbal products on international markets, e.g., in France, Australia, Germany, United Kingdom, Italy, and other European countries (IUCN, 1997; Robbins, 1996). Since demand has increased greatly, and supplies have declined, the price of goldenseal has increased dramatically. In the early 1990s, the price of goldenseal ranged from $18 to $24 per kg (Foster, 2000). In 1999, the price ranged from $66 to $110 per kg (Davis, 1999c; Foster, 2000). In 2000, the price of goldenseal was over $110 per kg, with some companies charging over $220 per kg (Foster, 2000; Price lists on World Wide Web). The current goldenseal shortage and the large increase in its demand appear to highlight the need for cultivated supplies to satisfy a growing domestic and international market (Foster, 2000).

Cultivation and conservation

Goldenseal is perceived to be at high risk of extinction due to excessive harvesting of wild populations to supply the market. The Nature Conservancy (U.S.) has assigned the plant a national rank of N4 and a global rank of G4, indicating that it is not susceptible to immediate threat; however, goldenseal is considered endangered, critically imperiled, imperiled, rare, or uncommon in all 27 U.S. states having native populations (USFWS, 1997). In Canada, goldenseal is considered threatened due to increasing potential for unrestrained wild harvest, as well as habitat loss (Sinclair and Catling, 2000a; White, 1991). Globally, goldenseal was added to Appendix 11 of CITES (Convention on International Trade in Endangered Species) in 1997 (CITES, 2000), which requires that goldenseal be artificially propagated for export (Environment Canada, 1999) and that national and international trade in roots, rhizomes, rootstocks, and bulk powdered herb will become more tightly regulated.

The actual risk of over-harvest eliminating wild populations is dependent on market conditions, as well as ecological characteristics. Increased cultivation may soon reduce the price of goldenseal to the point where collection of wild plants is not a threat to survival; however, this point is best reached before wild germplasm is lost. Results from a 1999 American Herbal Products Association survey (McGuffin, 1999) are encouraging in suggesting that the goldenseal market is in transition from wild to cultivated sources. Projections suggest that 37 Mg will come from cultivated sources in 2000 and reach 90 Mg or more after 2003. In terms of goldenseal ecology, the long-term effects of digging wild roots are unknown. Although there are abundant anecdotal references to a decline after digging (e.g., USFWS, 1997), there is also evidence for a beneficial effect of some level of soil disturbance (Sinclair and Catling, 2000b). While removal of large plants may reduce seed production, soil disturbance may allow increases in patch size in the long run, since goldenseal can produce new plants from root pieces and tips.

Objectives

Until the late 1990s, there was very little detailed information available on cultivation methods of goldenseal. Davis (1996a) summarized information from available literature (Foster, 1991; Haage and Ballard, 1989; Hardacre et al., 1962; Lloyd, 1912; Van Fleet, 1914; Veninga and Zaricor, 1976), and from farm and research station demonstrations, growers, and collectors. Davis (1999a) noted that many of the current recommendations for goldenseal cultivation are surprisingly consistent with those found in a 1914 USDA Farmers' Bulletin (Van Fleet, 1914), which was updated and released again in 1949 (Sievers, 1949). Over the past few years there has been a surge in research and interest in the cultivation of goldenseal, which has resulted in numerous publications from a wide range of sources, including universities, government agencies, commercial growers, public conferences, associations, and private researchers.

Our objectives are to (1) review information on goldenseal growth, from the literature and from a survey of goldenseal growers, and (2) present new information on natural populations. We hope this will increase interest in cultivation of goldenseal, and thus reduce the actual and perceived threat of over-harvest.

Methods

To gather information on optimal conditions for goldenseal growth, a literature search was conducted, using the keyword "goldenseal" alone and in combination with "cultivation," "farming," "propagation," and others, in five major sources: (1) AGRICOLA (bibliographic database for the National Agricultural Library and other institutions in agricultural and related sciences); (2) AGRIS (International System for the Agricultural Sciences and Technology); (3) BIOSIS (International Bibliographic Database for the Life Sciences); (4) CUBE (Carleton University and University of Ottawa collections, databases of the Center for Research Libraries in Chicago, Canada Institute for Scientific and Technical Information [CISTI], Norman Paterson School of International Affairs/The Institute of European and Russian Studies Resource Centre); and (5) the World Wide Web.

To further characterize growing conditions, data were collected in May 1998 from 21 natural goldenseal populations occurring in the northern portion of the range in Ontario, i.e., the northern part of the plant's range in North America. At each of the sites, population size (determined by number of stems) was estimated by direct count; plant species within goldenseal patches and tree species within a 10 m radius around a patch were recorded; and the amount of shade, soil type, and topography were noted. A "patch" constitutes a cluster of plants spaced within approximately 0.3 m from other plants and "sites" are at least 0.5 km apart. Patches give a very rough idea of genetic diversity because different patches are likely to be genetically different whereas plants within a patch could be identical due to clonal reproduction.

Shade was estimated based on a percentage scale indicating amount of canopy through which direct light was penetrating. A soil sample, one per site, was collected from 14 of the 21 sites, by pushing a metal cylinder [10 cm (3.9 inches) in diameter] to 9.5 cm (3.7 inches) depth into the soil within a patch of goldenseal. Soil samples were transported in plastic bags to ACUTEST laboratories in Ottawa for standard soil analysis (OMAFRA, 1988). Each sample was analyzed for pH, organic matter (percentage dry weight lost on ignition), P (extracted with sodium bicarbonate), K, Mg, Na, Ca (extracted with ammonium acetate), Mn (extracted with phosphoric acid), and Zn (extracted with DTPA, diethylenetriaminepentaacetic acid). For the 21 populations, soil texture (percentage sand, silt, and clay) was based on estimates from the soil sample or on local soil survey data. Data on natural conditions are valuable because in nature many stresses operate and the plant habitat may be restricted to optimal conditions.

Fifteen major goldenseal producers throughout North America were interviewed by telephone to help to further establish the requirements for optimal cultivation. Well known, reliable growers with established businesses and 5 to 18 years of first-hand experience were selected based on their identification in horticultural publications (Adam, 2000; Davis, 2000b), recognition by researchers and other growers, and their records of producing successful crops. Information obtained from the interviews included farm location, cultivation method, and soil moisture, texture, pH, and organic matter. Some growers did not want to be identified, and therefore, contributors to Table 3 are not named.

A method developed by Montford and Small (1999a, 1999b) was employed to estimate the "biodiversity friendliness" of goldenseal, compared to other crops, based on 26 criteria related to the predominant manner of cultivation (e.g., forest conservation; use of irrigation, biocides, and fertilizers; energy consumption; proportion of plant utilized; and others). The 26 criteria are assigned values of -1, 0, or 1, where -1 indicates the crop is relatively undesirable with respect to the biodiversity criterion, 0 indicates the crop has an average or undetermined impact, and 1 indicates the crop is relatively desirable with respect to the criterion. Simple averaging was used to calculate mean score (the more positive the score, the more "ecologically friendly" the crop). Information was obtained on other benefits of growing goldenseal, but no particular procedures were necessary to summarize these data.

Results and Discussion

Selection of forest site or artificial shade structure

Goldenseal can be grown successfully under an artificial shade structure consisting of steel or wood posts covered with polypropylene shade cloth or wood planks (wood lath structure) (Davis, 1996a, 1996b, 1999b; Konsler, 1987). The structure should be at least 2 to 3 m (6.6 to 9.8 ft) high and open on the sides, or with a maximum of two side curtains, to allow for adequate air circulation and to prevent overheating (Davis, 1999b).

Although goldenseal can be grown successfully under an artificial structure, some authors (Beyfuss, 1999; Davis, 1999b) and growers have suggested that a forest site is better than an artificial shade structure because the natural diversity and air circulation in the forest system help prevent major problems with disease and insects. Large populations of natural goldenseal thrive in mixed woods with oaks *(Quercus* spp.), maples *(Acer spp.)*, hawthorns *(Crataegus* spp.), walnut *(Juglans nigra* L.), hickories *(Carya* spp.), ironwood *[Ostrya virginiana* (Miller) K. Koch], basswood *(Tilia americana* L.), and ash *(Fraxinus* spp.) (Tables 1, 2). Similarly, optimal sites for cultivating goldenseal are within stands of mixed, deeply rooted hardwood trees such as oak, poplar (*Populus* spp.), walnut, and basswood (Cech, 1995, 2000; Davis, 1996b, 1999a, 1999b, 1999c; Konsler, 1987).

Table 2. Site characteristics for 7 goldenseal populations near the northern range limit in Ontario, Canada, for which only limited soil data were available.

	Site						
Parameter	1	2	3	4	5	6	7
Stems	283	165	640	203	45	261	10
Patches	2	5	7	5	1	1	1
Canopy [1]	E, Bas	Haw	Ob, Bas	Mr, Or	Haw	Haw	Ms
Shade (%)	70	50	60	70	60	70	50
Sand (%)	65	65	65	65	65	65	65
Silt (%)	20	20	20	20	20	20	20
Clay (%)	15	15	15	15	15	15	15

[1] Bas = basswood (Tilia americana L.); E = elm (Ulmus americana L.); Haw = hawthorn (Crataegus spp.); Mr = red maple (Acer rubrum L.); Ms = silver maple (Acer saccharinum L.); Ob = bur oak (Quercus macrocarpa Michx.); Or = red oak (Quercus rubra L.).

Plant species most frequently found associated directly with goldenseal in natural populations, and thus helpful in characterizing a goldenseal site, were wooly blue violet (*Viola sororia* Willd.), cut-leaved cranesbill (*Geranium maculatum* L.), false Solomon's seal [*Maianthemum racemosum* (L.) Link ssp. *racemosum*], white trillium [*Trillium grandiflorum* (Michx.) Salisb.], wild yam-root (*Dioscorea quaternata J.* Gemel.), enchanter's nightshade *(Circaea* spp.), inserted virginia creeper [*Parthenocissus inserta (A.* Kern.) Fritsch.], wild leek (*Allium triccocum Ai*ton), spotted touch-me-not (*Impatiens capensis* L.), snakeroot (*Sanicula* spp.), false mermaid (*Floerkea proserpinacoides* Willd.), trout lily *Erythronium* spp.), and wood anemone (*Anemone quinquefolia* L. var. *quinquefolia*). Patches of bloodroot (*Sanguinaria canadensis* L.), mayapple (*Podophyllumpeltatum* L.), white trillium, and blue cohosh [*Caulophyllum thalictroides* (L.) Michx] were often common and scattered throughout the woods where goldenseal occurred (pers. obs.; Davis, 1996b, 1999a, 1999b, 1999c; Konsler, 1987). The presence of these woodland herbs indicates appropriate woodland sites for cultivation. These authors suggest avoiding sites where undergrowth is very thick because of competition for resources and reduced air circulation. However, the most vigorous naturally occurring plants (i.e., largest and darkest green) grew in a woodland edge where undergrowth was thick, and raspberry *(Rubus* spp.), spice bush *[Lindera benzoin* (L.) Blume], and various introduced woody shrubs were common.

Cultivation requirements

Soil texture. Of the natural populations surveyed, 13 grew in sandy loam, 6 in clay loam, and 2 in loam soils. Fourteen of the 15 interviewed growers were successfully growing goldenseal in loam soils (7 growers specified sandy or clay loam, 1 specified sandy or silty loam; Table 3). Similar preferred soil type has been reported by researchers and experienced growers (Cech, 1995, 2000; Davis, 1996a, 1996b, 1999a, 1999b, 1999c; Konsler, 1987). Konsler (1987) and Davis (1996b) state that goldenseal tolerates any soil type except heavy clay or light sand, but some growers reported successful growth in predominantly clay or predominantly gravelly soils (Table 3). In so far as soil texture contributes to a large population, the largest natural populations grew in loam soils (Table 1). The healthiest natural population, based on number of stems, number of patches, leaf size, and leaf color (i.e., health defined in terms of size of the population, size of plants in the population, and absence of stress as suggested by color), occurred in clay loam soil.

Moisture. Natural populations of goldenseal occur on uplands in mesic woods, as well as on lowlands near rivers in dry mesic to mesic woods (Sinclair and Catling, 2000a). Many sources allude to a preference for moist but well-drained soils (Davis, 1996a, 1996b, 1999a, 1999b, 1999c; Hardacre et al., 1962; Li and Oliver, 1995; Maskewich, 2000; McLellan and Felton, 1998; Merwin, 2000; Reeleder, 2000). All 15 growers indicated that moist but well-drained soils are optimal for goldenseal growth; however, one grower grew one plot of plants successfully in what was referred to as "sloppy, muddy" conditions (Table 3).

(Continued on next page

Table 3. Information on goldenseal production obtained from interviews with 12 growers in the U.S. and 3 growers in Canada with 5 to 18 years experience in growing goldenseal. (Continued)

State/ Province	Method	Soil moisture	Soil texture	Soil pH	OM[1] (%)	Shade (%)	Comments
Ontario	woodland edge, raised beds	moist, not dry or sloppy	loam	7	high	50	Slight slope or level ground; composted manure added each spring; grows best in good forest soil (loam)
Ontario	woodland, raised beds	moist, well drained	sandy loam	5-6.5	70	70-80	Level ground; 3-4 yrs to harvest from rootstock; uses seed from 3-yr-old plants, germination is 90%
Oregon	woodland, no raised beds	moist, mesic forest	sandy or clay loams	no test	high	no test	Level ground; select good forest soil; give it as much light as it will take; grows well at forest edge; poor evidence for yield improvement with hardwood compost; leaf mulch is good to add
Tennessee	woodland	moist	loam	5.5-6.5	20	80-85	Level ground
Wisconsin	artificial shade, raised beds	well drained	sandy or silt loarns	5-6.5	3-4 dry wt	75-78	Level ground; little chemicals required; high labor costs ($28/hr); 4 yrs to harvest from root stock; 6 yrs to harvest from seed; seeds not difficult at all

[1] Organic matter content is measured as the percentage of the soil based on visual observation, unless otherwise indicated.

According to Konsler (1987), goldenseal grows best on slopes that provide good surface drainage; however, 6 growers reported excellent growth on level (or slightly sloping) terrain without raised beds, and 12 of 21 natural populations (60%) occurred on level land. Davis (1999a, 1999c) states that, under cultivation, raised beds should be constructed to promote good water drainage. Eight of the interviewed growers had success with raised beds, but seven also had success without them. Davis (1996a) suggests mulching with shredded leaves, chopped straw, and similar materials, to reduce moisture loss and weed growth, and increase winter protection. Seven growers reported the use of mulch to increase soil organic matter content rather than to protect the plants during winter. Disadvantages of surface mulch include its removal to allow emergence of seedlings and its provision of cover for certain pests such as slugs. Current research is directed at optimal mulch selection and it appears so far that plants perform best with hardwood and pine bark mulches (J.M. Davis, North Carolina State University, pers. comm., 2000). Bryant (1977), an experienced grower, emphasized the importance of preventing the beds from drying out in summer.

When grown under a forest canopy, goldenseal usually does not require irrigation, unless subject to drought conditions, which cause plants to drop foliage and become dormant earlier (Davis, 1999c). While some interviewed growers irrigate during periods of plant stress, many reported that irrigation is not necessary, and a few emphasized "no irrigation" (Table 3).

pH. The naturally occurring goldenseal populations occur in soil with pH ranging from 5.4 to 7.8. The largest populations were observed in soil with pH 6.3 to 7.8. Other large populations (>1000 stems) occurred within a soil pH range of 5.7 to 6.3. Three of the five smaller populations (≤ 241 stems) grew in soil with pH > 7.4 (Table 1). The healthiest population grew in soil with pH 6.4. Davis (1996a, 1998, 1999b) found optimal growth (100% survival, larger and healthier plant tops, higher fresh root weight) between pH 5.5 to 6.5, based primarily on experiments with goldenseal grown in pots with forest soil under a wood lath structure. Almost all interviewed growers reported optimal growth within the same pH range. However, one grower in New York State (listed in Table 3) reported successful woodland cultivation in soil with pH 4.8. Davis and Bir (1998) emphasize the importance of maintaining pH at 5.5 to 6.5 because of the sensitive relationship between pH and growth.

Soil fertility. Soil fertility (nutrients and organic matter) data for 14 naturally occurring goldenseal populations are presented in Table 1. According to fertility guidelines for native ornamentals (OMAFRA, 2000), all populations occurred in soil with high organic matter; adequate Mg, Mn, and Zn; but low P. Although population size and health are generally attributed to soil fertility, two of the largest populations (>1000 stems) occurred in soils with low K, and two with medium K levels. Of the smallest populations (≤ 241 stems), two grew in soils with low K, two with medium K, and one with very high K levels. The healthiest populations, based on number of stems, number of patches, leaf size, and leaf color, occurred in soils with medium K levels. Goldenseal is widely reported to prefer rich or fertile soils (Beyfuss, 1999; Davis, 1996a, 1999a, 1999b, 1999c; Kelly, 1977; Maskewich, 2000; Reeleder, 2000) high in organic matter (Beyfuss, 1999; Bryant, 1977; Davis, 1996b, 1999b; Hardacre, 1977; Konsler, 1987; McLellan and Felton, 1998). All 15 growers indicated that goldenseal grows best in very fertile soil high in organic matter. Most did not quantify the amount of organic matter in the soil, but merely indicated that it was "high." Other growers stated that, based on visual observations, organic matter content of their soils ranged between 15 and 70% (Table 3).

Before planting goldenseal, it is generally recommended that the soil be tested and fertility recommendations for native ornamentals be followed, if the soil testing laboratory does not provide any specific guidelines for goldenseal (Davis, 1996a, 1999a, 1999c). If tests indicate low fertility levels, addition of organic matter, such as composted manure, composted leaves, bone meal or cottonseed meal, is recommended (Bryant, 1977; Davis, 1996a, 1999c). Goldenseal does not benefit from addition of inorganic N or P, based on a 3-year experiment with application rates of 0 to 0.3 kg/m^3 N and 0 to 0.3 kg/m^3 P (Davis, 1998, 1999a, 1999b; Davis and Bir, 1998). None of the interviewed growers used chemical fertilizers, but instead added organic material such as leaf mold or composted manure (Table 3). Davis (1996a, 1999c) and Li and Oliver (1995) stress the importance of avoiding over fertilization as it can promote plant disease. According to Davis (1999c), goldenseal growing on high organic matter soils should be only lightly fertilized with an organic source of nutrients. Furthermore, Davis (1999c) suggests application of a balanced fertilizer at a low rate each spring, and Cech (1995), a grower with over 15 years of experience, suggests addition of compost each summer.

One interviewed grower reported that goldenseal "grows prolifically in [the] lime belt between North Carolina and Tennessee" (Table 3). However, T. Blakley (pers. comm., 2000) at the National Center for the Preservation of Medicinal Herbs in Rutland, Ohio, pointed out that there is no proof yet that goldenseal will produce more with higher Ca levels. In fact, preliminary results from an ongoing calcium study show that application of 2.2 to 5.6 Mg of Ca ha^{-1} (2,000 to 5,000 lb ac^{-1}) reduced leaf number and plant height, increased disease incidence, and caused earlier dieback (J.M. Davis, pers. comm., 2000).

Shade. Natural populations in the northern range limit of goldenseal were subject to 30 to 90% shade. Shade requirements reported by interviewed growers and in the cultivation literature fall within the upper portion of this range. Interviewed growers reported 70 to 87% shade as optimal for growth, except for one Ontario grower who reported optimal growth under 50% shade. Hardacre (1977) successfully grew goldenseal under 66% shade; other researchers and farm managers report 75 to 80% shade for optimal growth (Beyfuss, 1999; Davis, 1996a, 1999b; Li and Oliver, 1995; Merwin, 2000). Konsler (1987) reported 65 % shade as minimum tolerance. Conversely, natural populations thrived with as little as 30% shade. The healthiest natural population grew under 30% shade in a woodland edge, and one grower also found that goldenseal grew well at the forest edge (Table 3). The largest natural populations (>1000 stems) grew under conditions of 60 to 65% shade (Tablet). Although studies are not complete, Davis (1999a) reported that optimal plant growth occurred between 63 and 80% shade, and the highest plant stand counts and survival occurred under conditions of 47 to 63% shade. T. Blakley (pers. comm., 2000) suggested that 50% shade may be adequate in the northern U.S. states and southern Canada, but in the warmer south, 70% would likely produce better results. Davis (1996b, 1999a, 1999b, 1999c) and Konsler (1987) suggest avoiding cultivation sites in forests with no undergrowth (possibly it is too dark or dry). In natural populations, plant vigor was low (i.e., wilted, discolored, and shorter plants) with 90% shade and sparse undergrowth, but high (larger, greener plants) in sites with an even undergrowth and up to 70% shade.

Propagation. Goldenseal can be propagated from rhizome pieces, seed, buds, one-year-old seedlings, and/or root cuttings (Bryant, 1977; Davis, 1996a, 1998, 1999a, 1999b; Konsler, 1987; Li and Oliver, 1995; Merwin, 2000). It takes 3 to 5 years to grow harvestable roots from rhizome pieces, 5 to 7 years from seed (Cech, 2000; Davis, 1996a, 1999a; Merwin, 2000), and 4 to 6 years from root cuttings or seedlings (Davis, 1999a). Literature sources indicate that goldenseal is most easily and reliably propagated by dividing rhizomes in 2.5 cm (1 inch) or larger pieces, each with a bud and roots (Davis, 1996a, 1999a, 1999b, 1999c; Konsler, 1987).

From 24 to 27 August, 1999, at the start of senescence, the authors planted 100 rhizome pieces, each with at least 1 bud and numerous rootlets, at each of 5 sites where goldenseal grows naturally in Ontario. Based on analysis of variance, no significant difference in growth (leaf width and plant height) was found in either spring (4 to 6 May, 2000), summer (19 to 21 June, 2000), or fall (21 to 23 August, 2000) between small rhizome pieces [<2.5 cm (1 inch)] and larger pieces [<5 cm (2 inches), <7.5 cm (3 inches), and > 7.5 cm (3 inches)]. Studies on rhizome size (primarily its length) and rootlets, with or without buds, show that numerous healthy rootlets on a rhizome are important (i.e., little or no growth without) and latent buds produce plants when buds are not obvious or broken off (Davis, 1998). One of the interviewed growers stressed that bud size, rhizome size, and number of rootlets affect growth rate (Table 3). Ease of propagation was emphasized by many of the interviewed growers, and most prefer to use rhizome pieces that allow earlier harvest.

One grower reported positive results from passing goldenseal roots through a wood chipper, scattering the pieces over prepared beds, and raking them into the soil. Another grower claimed it was impossible for a goldenseal bed to be completely dug out because root fragments left in the soil will start a new population. Davis (1998) also reports that small root pieces left in the soil after harvest produce new plants the next year. Some have had success by simply layering rootlet cuttings in a bed, letting them grow for a year, and transplanting them (Davis, 1998, 1999a).

Literature on cultivation (Davis, 1996a, 1999c) and information from interviewed growers (Table 3) indicates that propagation of goldenseal by seed is difficult and unpredictable. Cech (2000) places cultivation of goldenseal by seed in the "extra care" category (compared to "challenging" or "easy"). Germination rates of purchased seed range from 0 to 90% (Davis, 1999c). Davis (1999b) reports that many growers achieve only 30 to 40% germination the first spring after sowing. She obtained about 33% germination the first year, but up to 94% the second year after sowing. Through experimentation, Davis (1998) found no effect of extraction method or disinfecting treatment on germination, but that sowing time and temperature were critical. The highest germination percentage was with seeds held at room temperature (21°C) for 2 weeks before planting, and the highest germination (up to 88%) was with seeds sown in August (shortly after extraction), compared to late fall or spring. Interestingly, one interviewed grower emphasized that propagation by seed was not difficult (Table 3).

Diseases and pests. None of the 21 wild populations of goldenseal showed evidence of disease or pest problems. Similarly, cultivated goldenseal rarely suffers from disease or pests when grown in small plots in the woods (Davis, 1999a, 1999c). Some plantings may be affected by botrytis leaf spot and/or slugs (Davis, 1999c; Li and Oliver, 1995). Removal of affected foliage and mulch provides reasonable control for botrytis (Davis, 1999a), and successful methods of control for slugs have been documented (Davis, 1999a, 1999c). However, as goldenseal has been increasingly cultivated, there are now more reports of diseases (caused by *Alternaria, Rhizoctonia,* and *Fusarium*) occurring under artificial shade structures, but not in the forest (Beyfuss, 1999; Davis, 1999a, 1999c). The more intensive the production system used, the greater incidence of disease (Davis, 1999b). The chance of diseases can be reduced by proper sanitation practices, adequate air and water circulation, and avoiding over fertilization (J.M. Davis, North Carolina State University, pers. comm., 2000). None of the interviewed growers reported any diseases or pests associated with their production practices.

Commercial production

Some ginseng farmers have taken advantage of goldenseal's potential as a rotation crop (Merwin, 2000). Its value results from the perception that ginseng cannot be grown continuously due to deterioration of soil quality. However, this may be overstated since soil quality adequate for ginseng production can be maintained (T.S.C. Li, Agriculture and Agri-Food Canada, pers. comm., 2000). Ginseng farmers have noted that goldenseal has similar cultural requirements and, consequently, there is substantial potential profit in taking advantage of an existing ginseng plantation to grow goldenseal. The raised beds, forest site, or shade apparatus is already in place and similar equipment can be used in crop management and harvesting. It is generally conceded that goldenseal is less difficult to grow than ginseng because of the greater tolerance of the former crop to higher light intensity, wetter conditions, and diseases and pests (Beyfuss, 1999; Bryant, 1977; Cech, 1995; Davis, 1996a, 1996b; Konsler, 1987; Table 3). Two growers indicated that goldenseal is more tolerant of drying out and grows well in much wetter conditions, compared to ginseng, and goldenseal roots are less likely to rot (Table 3). Goldenseal is not affected by the most serious diseases of ginseng, e.g., leaf and stem blight caused by *Alternaria panax* and root rot caused by *Phytophthora cactorum* (Beyfuss, 1999; Davis, 1999a). In fact, goldenseal may be grown successfully in locations where ginseng crops have failed due to root rot caused by *P. cactorum* (Davis, 1999a). Davis (1998) found that by the second year after planting old ginseng beds half with goldenseal and half with ginseng, 28% of the ginseng remained compared to 80% of the goldenseal, at one site, and 83% of the goldenseal was left, but none of the ginseng, at another site. Cech (1995) reports that some growers mix goldenseal plants in with their ginseng to "purify" the soil. One of the growers reported use of this strategy (not recorded in Table 3). One farmer growing both ginseng and goldenseal referred to them as "the king and the queen," the "queen" (goldenseal) being more robust and reliable.

Current research

Several cultivation studies under the direction of J.M. Davis are underway at North Carolina State University (Davis, 2000a). Included are studies on factors influencing quality grades (based on alkaloid content), propagation methods (rhizome pieces and rootlets), seed germination, spacing of seedlings and rhizome pieces (5 cm x 5 cm to 30 cm x 30 cm), mulches (seven types), and shade (four levels). She is also investigating the potential of goldenseal as a rotation crop for ginseng in terms of soil improvement (Davis, 1998). J. Simon at Purdue University is testing whether goldenseal is more subject to diseases under a shade structure compared to a forest canopy (Davis, 1998). Research on the cultivation requirements of goldenseal is also being conducted at the National Center for the Preservation of Medicinal Herbs in Rutland, Ohio. Studies include identification of diseases and pests; importance of solar direction; comparison of yield from seed vs. rootstock and from raised beds vs. planting in ground; light, fertility, and pH requirements; mulches; seed stratification techniques; drying methods; and storage methods (McNeill et al., 2000; T. Blakley, National Center for the Preservation of Medicinal Herbs, pers. comm., 2000). Research currently being conducted by R.D. Reeleder at Agriculture and Agri-Food Canada's Southern Crop Protection and Food Research Centre features alternative methods of generating planting stock to ensure that crops are not established from wild-collected roots, to halt decline of natural populations. Longer-term goals at this Centre involve remedies for pest control (Reeleder, 2000). A. Sinclair (Catling and Sinclair, 1998; Sinclair and Catling, 2000a, 2000b; Sinclair et al., 2000) is studying habitat requirements and effects of disturbance that relate to growing conditions and cultivation. Two recent conferences (Louisville, Kentucky, 9-11 May 2000, and Leeds, New York, 7-9 September 2000) have raised awareness of the potential of ginseng and goldenseal crops. The Louisville conference, organized by T. Jones, University of Kentucky Extension Horticulture Specialist, featured workshops to teach growers how to produce ginseng and goldenseal under semi-natural and organic conditions, resulting in higher cash value.

Other considerations

The demand for goldenseal may not reach the point of allowing it to become a significant crop or even a significant rotational crop in ginseng cultivation, in terms of hectarage, but there is little doubt that it will become much more widely grown on a commercial basis. Considering this possibility, there are several benefits of growing goldenseal to bear in mind.

Environmental friendliness. Goldenseal has an approximate "biodiversity- friendly" score of 17, making it one of the crops that contributes most to biodiversity protection. Its very high score is a consequence of various characteristics such as: (1) it requires relatively little agricultural input (i.e., fertilizers and pesticides); (2) it contributes to protection of wild species; (3) it requires relatively low energy for maintenance and harvest; (4) it has a high value per ha and relatively low hectarage requirement; (5) it can be grown in rotation thus reducing the need for agrichemicals; and (6) its flowers produce food for pollinators.

Sustainability and germplasm protection. Reduction of the increasing threat to natural populations as a result of cultivation could decrease the likelihood of loss of goldenseal germplasm. The germplasm may prove valuable in crop development if goldenseal gains popularity as a crop.

Low fertilization and energy requirements. Davis (1998, 1999a, 1999b) found that addition of inorganic N (ammonium nitrate) and P either reduced growth or had little effect, indicating that fertilizer requirements are generally low. Minimizing fertilization reduces both actual and environmental costs. Less expensive organic sources of fertilizer, such as leaf compost, manure compost, bone meal, or cottonseed meal, have been recommended by researchers and growers as more effective for goldenseal production (Bryant, 1977; Davis, 1996a; Hardacre, 1977; McNeill et al., 2000; Reeleder, 2000).

Availability of planting stock

Suppliers of plant propagation material are readily available on the World Wide Web; however, a survey by the American Herbal Products Association indicates that most material is obtained from wild sources (McGuffin, 1999). Suppliers and/ or local natural resource departments may be able to ensure that source material has originated from cultivation. Current research is directed at alternative methods of generating planting stock (Reeleder, 2000) and optimizing cultivation techniques (McNeill et al., 2000), to reduce collection from wild populations. Suppliers are also encouraging growing the plant from seed (Cech, 2000). Regional natural populations contain characteristics, including local climate and pest adaptation, and possibly genetic variation in blight and drought resistance, alkaloid content, and other characteristics, necessary to develop and maintain a viable crop in local areas.

Summary and Conclusions

There has recently been much increased interest in goldenseal cultivation. It is relatively easy to grow and may provide a useful diversification crop. At the same time cultivation may increase availability of this medicinal herb and contribute to the protection of natural populations. As a crop, goldenseal is considered relatively inexpensive, can be grown throughout a large region of North America, and contributes in a number of ways to the goals of sustainable agriculture.

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