

Asian and American Ginseng—A Review

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Summary. The ginseng industry has expanded rapidly in recent years. Asian and American ginseng are cultivated around the world. Ginseng products in various forms are increasingly popular, and its consumers are no longer limited to Asians. More knowledge is needed about the horticultural characteristics, cultural methods, disease control, drying and storage procedures, and technology for value-added products. Once-secretive information about ginseng and its culture is gradually becoming available, especially from the orient. Growers and researchers are eager to know more about Asian and American species of this high-value crop.

Asian ginseng (*Panax ginseng* C.A. Meyer) and its close relative, American ginseng (*Panax quinquefolium* L.) (Evans, 1985), are perennial aromatic herbs originating in China and Canada, respectively (Bae, 1978; Li, 1973). It is one of a few Chinese medicinal herbs used frequently without blending with other herbs (Lu, 1986). Asian ginseng, which has been used for more than 4000 years (Baranov, 1966), is purported to stimulate metabolism, thereby maintaining and improving health (Hu, 1977). It also may act as an anti-hypoxia to stress (Liu and Xiao, 1992) and increase reproductive potential in animals (Rim, 1979). Recently, it has been reported that American ginseng may have insulin-like activity (Lu, 1986; Okuda and Yoshida, 1980), influence necrologic reactions (Lewis, 1988), reduce total cholesterol level (Muwalla and Abuirmeileh, 1990), and improve heart and blood circulatory

functions (Kaku et al., 1975). Ginseng products involving Asian and American ginseng are increasingly popular and are readily available in pharmacies and health food stores around the world.

China is the largest ginseng producer in the world (Anonymous, 1990). The major production regions are in the northeast (Fig. 1) between the latitudes of 39° and 47°N (Evans, 1985), where 50% or more of China's total Asian ginseng crop is produced each year. Production increased from 1561 t of dry root in 1985 (Yu, 1987) to 3350 tin 1990 (Anonymous, 1990). South Korea, which ranks second in production, has two major growing regions centered around the cities of Daejeon and Chuncheon between the latitudes of 36° to 38°N. The Korean crop increased from 2200 tin 1982 to 3320 tin 1988 (Proctor et al., 1990). The United States and Canada are the major American ginseng-producing countries, from southern Canada (Ontario and British Columbia) to central Alabama and from the east coast to just west of the Mississippi river (Persons, 1986) production increased from 370 t in 1983 to 800 t in 1990 (Anonymous, 1990).

China has the greatest number of native *Panax* species in the world (Liu, 1988; Liu and Xiao, 1992; Xiao et al., 1987). They include Asian ginseng (*Panax ginseng* C.A. Meyer), Chia-jen-shen (*P. pseudo-ginseng* Wall.), San-chi (*P. notoginseng* (Burk.) F.H. Chen), Chu-chieh-jen-shen (*P. japonicum* C.A. Meyer), Yu-yeh-shen (*P. japonicum* var. *bipinnatifidus* C.Y. Wu and K.M. Feng), Chai-yeh-chu-chieh-shen [*P. japonicum* var. *angustifolius* (Burk.) Cheng and Chu], Chu-tzu-shen [*P. japonicum* var. *major* (Burk.) C.Y. Wu and K.M. Feng], Chaing-chuang san-chi (*P. zingiberensis* C.Y. Wu and K.M. Feng), and Ping-ping-san-chi (*P. stipuleanatus* H.T. Tsai and K.M. Feng). In addition, China also has Siberian ginseng [*Eleutherococcus senticosus* (Rupr. and Maxim.) Maxim.], a common Asian forest shrub

in the Araliaceae family with properties similar to that of ginseng (Baranov, 1966). American ginseng (*P. quinquefolium* L.) and dwarf ginseng (*P. trifolium* L.), both native North American ginseng species (Philbrick, 1983; Schorger, 1969), also are widely cultivated in China.

Morphological classification within Asian and American ginseng

Cultivated *P. ginseng* can be divided into two major types based on the shapes of rhizome, round and long, and can be identified by color as well (Liu, 1988).

In the round rhizome type, rhizomes are short, thick, and white, with shorter main roots with many side branches (Fig. 2). The plant grows rapidly and produces high root yields. The plants normally set seeds in the 3rd year. The leaves have many uniform serrations on the leaf margin. There are two cultivars in this category, 'Big Round Rhizome' and 'Medium Round Rhizome'. In Korea, most farmers grow 'Big Round Rhizome', which has the most vigorous growth habit. A third of the plants have more than one prong in the first year, and more than half of the fresh roots weigh more than 100 g after 6 years of cultivation.

In the long rhizome type, rhizomes are long and thin with creamy yellow short main roots (Fig. 2). There are fewer side branches than on the round rhizome type. Root shape is considered highly desirable, but this type of ginseng grows slowly and root yields are low. It does not produce seeds until the 4th year. Serrations on the leaf margin are deep and nonuniform. There are two cultivars in this category, 'Round Shoulder' and 'Long Neck' (Liu, 1988).

There is no confirmed evidence of genetic or morphological diversification within *P. quinquefolium*, although I have observed considerable variation in commercial ginseng gardens in British Columbia and Ontario, Canada. Breeding and selection likely will improve ginseng yields and disease resistance in the future.

Ginsenosides

Ginsenosides are the major active components in Asian and American ginseng. Total ginsenosides vary depending on species, growing environ-

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ment, and extraction method. For example, 6-year-old Asian ginseng roots from the Tong-hua district of China have higher total ginsenosides, on a dry weight basis, than roots from the Ji-lin district (6.4% vs. 4.4%, respectively). In addition, total ginsenosides in cultivated *P. ginseng* per unit of root dry weight increases with the age of the roots (Xiao et al., 1987). In Japan, ginsenosides in Asian ginseng approach maximum levels in late summer after 4 years of cultivation (Soldati and Tanaka, 1984).

Researchers in Russia and Japan have spent decades trying to isolate the active ingredients of ginseng (Liu, 1988). By 1992, 28 ginsenosides, coded as Ra, Rb, Rc, etc., had been isolated and identified in root, stems, leaves, flowers, and flower buds of the ginseng plant (Liu and Xiao, 1992; Nagasawa et al., 1980; Shibata et al., 1966). The effects of each of the ginsenosides on humans has been documented (Lewis, 1988), but their sus-

pected synergistic effects remain a mystery.

There are differences in ginsenoside levels in different *Panax* species. Total ginsenosides per unit of 6-year-old root dry weight of *P. ginseng*, *P. quinquefolium*, and *P. pseudoginseng* are 3.8%, 4.1%, and 6.2%, respectively (Liu, 1988). Ginsenosides are also different in various parts of the ginseng plant. Total ginsenosides in leaves and flower buds were 31%–172% and 118%–226%, respectively, higher than in the main root in all three species (Liu, 1988). In contrast, Kwon et al. (1991) found that crude saponin and ginsenoside contents were highest in the taproot and lateral roots compared to other parts of the ginseng plant.

Cultural management

Seed collection and germination. In Korea, Asian ginseng seeds are harvested for propagation from 4- or 5-year-old plants in the middle of

the ginseng bed. Each in florescence is thinned to 20 to 30 flowers and further thinned to 10 to 20 berries at the green berry stage. Seeds are harvested when the berries are bright red. For good germination and seedling growth, an average seed weight of 50 g/1000 seeds is recommended.

The embryo in freshly harvested seeds of Asian and American ginseng is not fully developed (Baranov, 1966). Sprouting of ginseng seeds, under natural conditions, takes 18 to 22 months. For seeds to germinate, they must progress through stratification consisting of two stages: the completion of anatomical development and physiological after-ripening (Xiao et al., 1987). These are highly vulnerable stages in the life cycle of ginseng during which any improper treatment can cause high seed mortality and poor germination (Lewis and Zenger, 1982).

When held at the optimal soil temperature range of 18 to 20°C, the embryo continues to develop in the

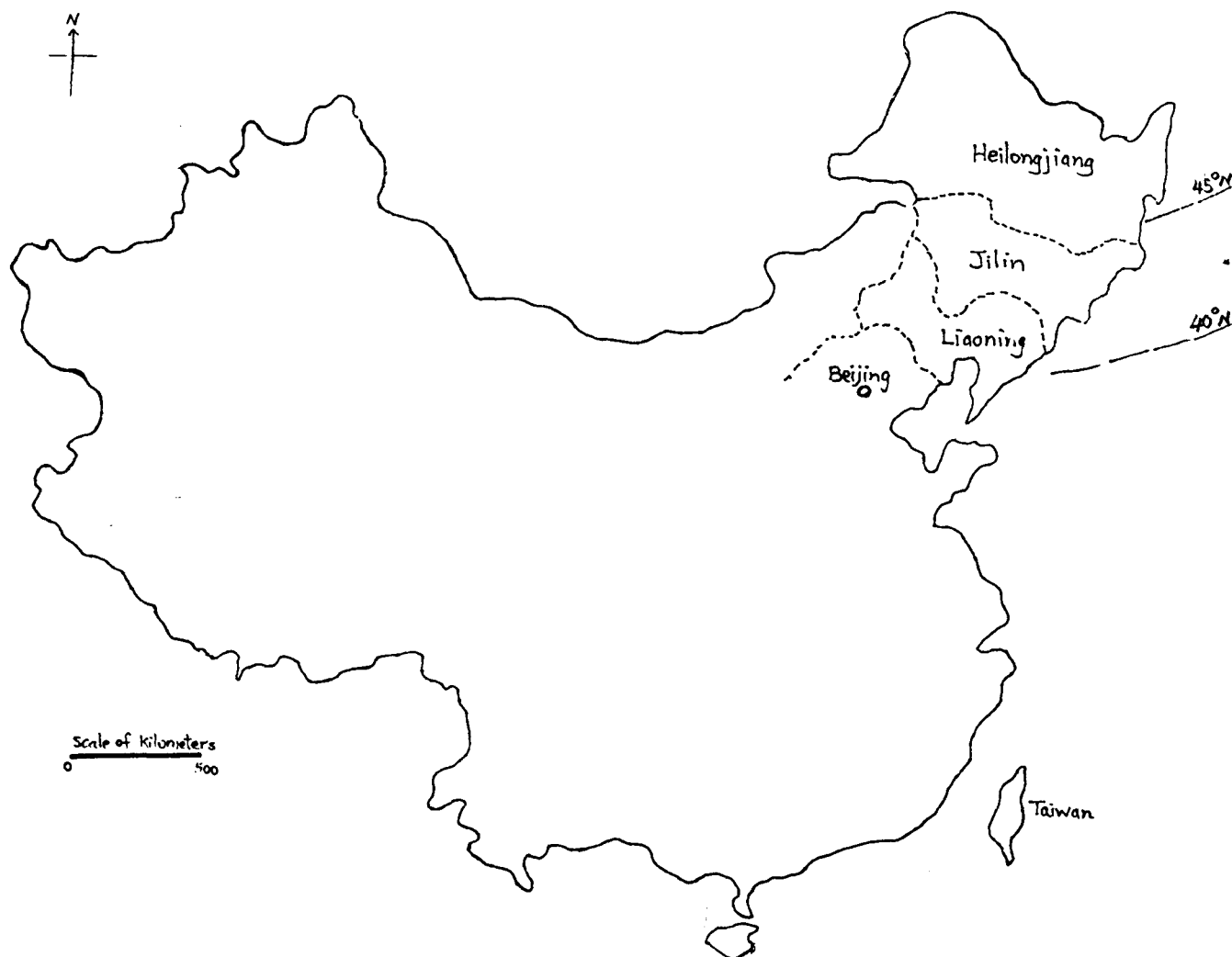


Fig. 1. The major Asian ginseng production regions in China (Xiao et al., 1987).

newly picked seed. Cotyledons, hypocotyl, radicle, and epicotyl become visible as the embryo continues to develop and reaches a length of 3 to 3.5 mm (Yu and Kim, 1992). Experimentally, Choi (1977) reported that the development of ginseng seeds can be enhanced with chemical treatments such as gibberellic acid (GA_3), kinetin, or benzyladenine. In a nonconfirmed report, Grushvitzky and Limarj (1965) indicated that a treatment consisting of soaking seeds in 500 to 1000 ppm gibberellic acid for 24 h followed by rinsing shortens the anatomical development stage from 3 to 4 months to about 10 days and the total dormant period from 22 to 4 months.

Xiao et al. (1987) reported that the emergence rate for GA_3 -treated seeds was two to three times higher than for untreated seeds. Furthermore, the average root weight of plants arising from treated seeds was 1.9 times that of nontreated seeds. This is a widely held belief in China and Korea, but it has not been confirmed in North America. If true, it indicates that the gibberellin treatment enhanced embryodevelopment during the anatomical development stage, compared to the conventional procedure, in which seeds are planted when the soil temperature is 18 to 22°C to promote embryodevelopment.

Neither Asian nor American ginseng seeds will germinate without going through a physiological after-ripening (stratification) stage. Controlled experiments have indicated that this requirement is met optimally when a 1 seed : 2 sand mixture (v/v) is maintained at 10% to 15% moisture content and held at 2 to 4°C for 3 to 4 months (Lee et al., 1984). However, it appears that the length of stratification requirement varies with region. In Russia (lat. 38°N, long. 137°E), seed stratification is completed within 5 weeks. In contrast, only 10 days are required in Japan (lat. 35°N, long. 132°E) (Xiao et al., 1987). This procedure cannot be replaced or shortened with any growth regulator treatment. During this stage, the embryo continues to increase in size, and germination occurs when the embryo reaches about two-thirds of the seed size.

Seeding depth also affects germination. In one study (Liu, 1988), seeding at a depth of 5 cm gave a 22% higher emergence rate than at depths of 3.3 and 6.6 cm. My own unpub-

lished results indicate that seeding of Asian and American ginseng at depths of 1.3, 2.6, or 5.1 cm gives significantly higher emergence rates than seeding at 7.7 cm.

Berries on the flower head mature unevenly. At picking time, some of the berries on the top of the cluster are still green. Seeds collected from berries at different stages of maturity will differ in seed emergence rate and total yield. Seeds from fully ripe, red berries give higher emergence rates (80%) than purple (40%) or green (10%) berries (Liu, 1988).

Seeding periods, spacing, and seedling transplanting. The most common seeding periods are spring and fall for Asian ginseng in China and Japan, while American ginseng usually is planted in fall. Germination of Asian ginseng occurs immediately upon spring planting when fully stratified seeds are used. Chemically treated current-year green (nonstratified) seeds can be used for fall planting. They will germinate the following spring.

In Korea, there are three seeding periods, spring, summer, and fall. As time of seeding affects germination percentage the following spring, it is suggested in Korea that seeds of *P. ginseng* be planted as early as possible, preferably in late July or early August while soil is warm (Bae, 1978). Fall planting, from mid-September to November, is one of the most popular seeding periods, using current-year chemically treated or stratified seeds. Although germination rate is slightly lower than from spring seeding, there is less risk of disease (Liu, 1988).

In the Orient, direct seeding involves nursery plantations. Seeds are planted at a rate of 750/m², and seedlings are transplanted 1 year later. Seed and seedling selection are considered very important in Asia for final effect on root weight and yield (Chung and Chang, 1982). In Japan, only the best seeds and seedlings are used for planting and transplanting.

A Japanese study showed that 22 Asian ginseng seedlings transplanted to a space of 1 m² gave the highest return and that this spacing was most economical (Xiao et al., 1987). Park (1987) reported that the optimum planting density was 20 plants/m² for yield and proportion of high grades. Konsler (1982) reported that root size and total yield of American ginseng are affected strongly by plant spacing.

Furthermore, excessive crowding encourages the spread of disease in the field (Putnam, 1984).

Flowering, flower thinning, and its effect on yield. *Panax ginseng* and *P. quinquefolium* are self-pollinating crops (Bae, 1978, Lewis and Zenger, 1983). Flowering begins in the 2nd or 3rd year and lasts for 2 to 3 weeks. Flowers pollinate each other within the inflorescence. Natural cross pollination among plants is between 11% to 27% (Xiao et al., 1987).

Two to 3 days after flowering, the embryo begins to develop, and small light green berries are formed 2 weeks later. The color of the berry becomes dark green, then purple, and finally red.

Flower thinning significantly affects root yield. Removal of all flowers increases total yield by nearly 50%. In China, it was reported that the total yield was reduced by 28% to 34% if plants were allowed to set seeds in the year of harvest (Liu, 1988). In 6-year-old plants, total yield was reduced by 34% if plants were allowed to produce seeds each year before harvest. Similar results also were reported from Japan. The normal practice is to remove flowers before they open in mid-May to mid-June. These flowers can be dried and have a high cash value for use in tonics. There are no reports on flower-thinning effects on yield for American ginseng, but field experiments are underway in Canada.

Shade and light. Ginseng is a shade-loving crop and is traditionally grown under an impermeable straw thatch in the Orient. In Korea, production of Asian ginseng in an experimental plot was higher when shaded with thatch than with a polyethylene net (Kim et al., 1990). Research aimed at developing a different shade material in Korea (Cheon et al., 1991b; Proctor et al., 1990) and China (Liu, 1988) has been reported. Natural shade (Persons, 1986) and wooden lath are used by some ginseng growers in the United States and Ontario, Canada, but these practices are less common among new growers. Only woven synthetic fabrics are used by growers in British Columbia, Canada (Bailey, 1990) for American ginseng production.

Panax quinquefolium can tolerate higher light intensity than *P. ginseng* (Xiao et al., 1987). It is difficult to determine what light intensity is most

suitable for growing ginseng. Generally, regions of higher latitude should have greater light intensity than lower latitude regions (Liu, 1988). In Korea, it was reported that higher light intensity during growth had no effect on the yield of *P. ginseng* (Park, 1987), and 8% to 18% full sunlight produced maximum yield (Cheon et al., 1991a). In Japan, the best light levels for ginseng undershaded cultivation was given by Yang (1974) as 3000 to 4000 lux.

Temperature. The ideal air temperature for growing Asian ginseng is 16 to 18°C (Yang, 1974). Growth slows considerably when the temperature is >30°C. In the spring, seeds progress toward germination when the soil temperature reaches 4 to 5°C, and they start to emerge when the air temperature reaches 10°C (Liu, 1988). Ginseng needs 15°C or higher air temperature to produce flowers and 20 to 25°C to set seeds. Lee et al. (1984) indicate that optimum soil temperature for root growth is 15°C. Asian ginseng plants

start to die back when the air temperature reaches 4°C. Dormant 1-year-old ginseng roots are damaged by -12°C, although older roots may tolerate soil temperatures as low as -17°C (Xiao et al., 1987). My own unpublished results indicate that the roots of *P. quinquefolium* failed to sprout and decayed when potted 1-, 2-, and 3-year-old roots were exposed to root zone temperature of -6, -7, and -7°C, respectively, and showed frost damage on the leaves 2°C above these temperatures. Kinsler (1986) reported that 1-year-old roots stored between layers of damp sphagnum moss became flaccid when the temperature dropped to -15°C. In general, ginseng roots do not tolerate sudden temperature fluctuations, as they predispose them to root rot diseases (Oliver et al., 1992).

Water. Water requirements vary with different stages of plant development and with air and soil temperature. *Panax quinquefolium* can tolerate higher soil moisture than *P. gin-*

seng (Ren and Wang, 1989). In general, ginseng needs a soil moisture content of 40% of field capacity for germination, about 35% for leaf growth, and 45% to 50% for flowering and seed set (Liu, 1988). After seed harvest, root growth continues at a very rapid rate, and moisture requirement is about 40% to 50% of field capacity. In Japan, it was reported that soil moisture of 50% to 60% of field capacity gave the best growth (Park and Lee, 1980), but excessive soil moisture enhanced root rot.

Soil. As a root crop, Asian and American ginseng grow best on well-drained, sandy loam soils. Too many rocks in the soil allow water to percolate quickly, resulting in fluctuation of soil temperature. If the soil is too sandy, roots will produce many small branches (so-called "cow's tail"), and be of little value in the market (Xiao et al., 1987). The best soil pH range for growing ginseng is 5.0 to 6.5. Levels above pH 6.5 will cause physiological

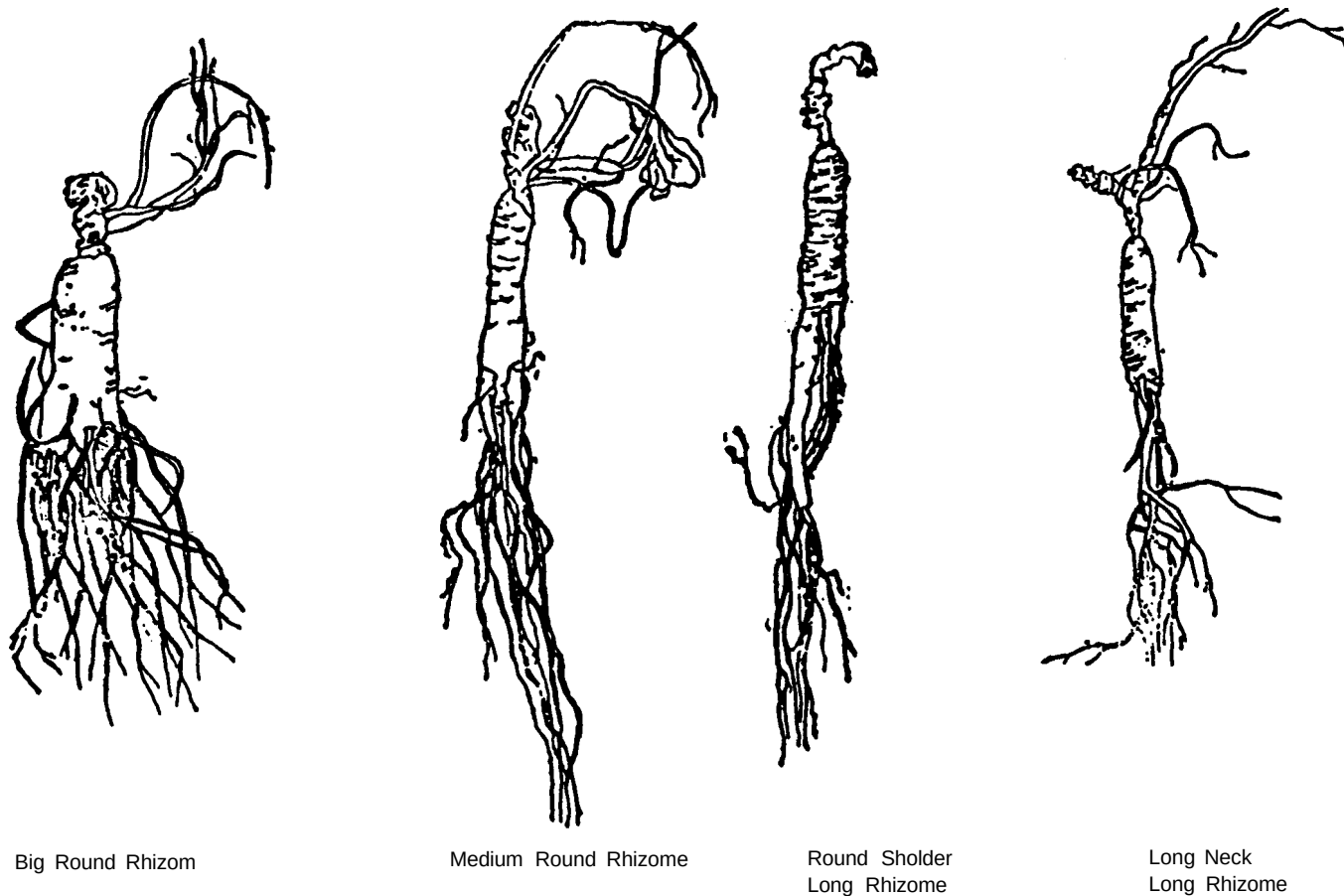


Fig. 2. Morphological classification of 6-year-old Asian ginseng roots (Liu, 1988).

disorders such as nutrient deficiency (Persons, 1986). In Japan, it was reported that pH 5.0 to 5.8 is suitable for growing ginseng (Liu, 1988). In Korea, researchers claim that slightly acidic soil with pH 5.5 to 6.0 is better (Hong, 1978).

Fertilizer. In Japan and Korea, the rates of fertilizer used for Asian ginseng are 28.5 kg N/ha 6.7 kg P/ha; 31.5 kg K/ha; with a ratio of 4N-1P-6K (Liu, 1988). Too much N fertilizer results in rapid vegetative growth and poor-quality roots, with defects such as smooth root surface and low total ginsenosides. Khwaja et al. (1984) recommended fertilizer requirement for American ginseng based on soil and plant tissue analyses. My own unpublished data indicate that the seed emergence rate of American ginseng was reduced significantly by high levels of N in the soil. Even though the phosphate requirement is 15% to 25% that of N, it has important effects on root growth, root hair development (Konsler and Shelton, 1990), and drought and disease tolerance (Whetzel and Rosenbaum, 1912). Foliar application (once a month) of 2% phosphate fertilizer [$\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot 2\text{CaSO}_4$] is reported to increase seed production of *P. ginseng* by 29% and root weight by 35% (Liu, 1988). The application of K increases disease resistance and the fiber content of roots (Liu, 1988). Li and Wallis (1994) reported that higher phosphate levels increased American ginseng seed emergence and reduced seedling mortality rate, but did not affect fresh root weight.

In Japan, ammonium sulphate and urea are not recommended for Asian and American ginseng production. These fertilizers are believed to affect seed germination adversely and induce rusty root disease (Liu, 1988). The roots of 1- or 2-year-old seedlings are small and shallow, and fertilizer application on the soil surface may cause root damage and induce disease caused by the fungus *Cylindrocarpon destructans*. Heavy fertilization or excess unused nutrients in the soil, especially N, induce root rot caused by *Phytophthora* (Xiao, et al., 1987) and other injuries (Whetzel, et al., 1916).

Harvesting. In the Orient, Asian ginseng is harvested in the middle of October after 6 years of cultivation. Depending on the soil texture, average 6-year-old roots are about 7 to 13 cm in length and 2 to 5 cm in diameter,

and fresh weight is about 40 to 80 g (Liu, 1988). In China, 6-year-old ginseng yields between 2500 and 3400 kg of dry root/ha are considered above average (Liu, 1988; Xiao et al., 1987). In British Columbia and Ontario, average American ginseng yields after 4 years of cultivation under polypropylene or wooden shades are around 3300 and 3150 kg·ha⁻¹, respectively (Oliver et al., 1992). Information supplied by the Wisconsin Dept. of Agriculture, Trade and Consumer Protection, and Agriculture Canada revealed that total yield of American ginseng in Wisconsin, British Columbia, and Ontario in 1992 was 733 and 490 Mg, respectively. It is difficult to get exact Asian ginseng production figures—the best estimations were 4000 and 1700 Mg from China and Korea, respectively (Anonymous, 1990).

Drying. In Asia, roots are washed thoroughly after harvesting, graded according to size and quality, and divided into three groups based on their length (longer than 20 cm, 10 to 20 cm, or shorter than 10 cm). Because the temperature required for root drying is based on the size of roots, different sizes should not be dried together. This procedure is worthy of consideration in North America because ginseng growers normally do not grade their roots after washing. The ideal moisture content in dry roots is 8% to 10%. If the drying process is started at lower or higher than 38°C, the temperature should be adjusted to 38°C when the root moisture content reaches 30% to 35%. This is an essential step to avoid root browning (Xiao et al., 1987).

Diseases and other disorders

A recent review of the literature revealed that there are 64 fungal and eight bacterial pathogens infecting *Panax* species (Li and Utkhede, 1993). Most economically significant diseases are caused by fungal pathogens. They infect roots, flowers, and berries and result in reduced seed set and yield. Bacterial diseases on ginseng roots have been reported in China, Korea, and Russia (Lee, 1977; Xiao et al., 1987). Other diseases, such as those caused by viruses, mycoplasma-like organisms, and nematodes, have been reported in Asia and North America (Latysheva and Sevryuk, 1981; Li, 1983; Li and Utkhede, 1993; Van Hook, 1904; Vrain, 1993; Xiao et al., 1987).

Physiological disorders

Winter injury. Winter injury can result from freezing or from excessive soil moisture in the spring (Liu, 1988; Xiao et al., 1987). Although ginseng is known to survive to air temperatures of -35°C, large vigorous ginseng roots can tolerate winter damage better than small ones. When the ground thaws and soil moisture increases dramatically with rain or melting snow, winter injury can occur if the temperature drops a few degrees below freezing. In the spring, buds start to grow when the ground temperature reaches 5°C. If the temperature suddenly drops to below freezing during this time, the young buds may be injured or killed. In some cases, the roots are still alive and may regrow again the next year. In early spring, if the raised bed has excess water and the bottom base soil is still frozen, drainage problems will result. The excess water may promote root-rot problems by fungus such as *Phytophthora cactorum*. Coarse soils are subject to large soil temperature fluctuations between day and night, which can be detrimental (Liu, 1988).

Winter injury can be prevented by covering the soil bed with straw in ginseng gardens. Spring planting can avoid the temperature fluctuations common in fall and early spring. If it is necessary to seed in the fall, planting as late as possible, just before the ground freezes, is recommended, as the temperature differences between day and night during late fall are less than in early fall. In Asia, ginseng growers cover ginseng beds with plastic immediately after planting to avoid high soil moisture caused by rain in the spring and fall.

Root split. Soil moisture that is too high in fall and too low in spring causes the roots to split (about 5% to 15% of the roots may suffer this disorder) (Xiao, et al., 1987).

Sunburn. Direct sunlight may cause sunburn to leaves, a condition often seen near the edges of a covered ginseng garden.

Red skin or rusty roots. Symptoms of this disorder are dry feeder roots and red or rusty color on main roots. It does not appear to affect ginsenoside content (Ahn, 1992). In the early stage, root skin becomes yellow, with no symptoms on the stem and leaves. Later, root skin becomes

brown or red brown; root surface becomes rough, thick, hard, crisp, and split; and finally the roots rot (Liu, 1988; Zinssmeister, 1918). In Korea, it was reported that this disorder is caused mainly by high moisture and iron in the soil (Korean Ginseng Tobacco Research Institute, 1987). In China, it was reported that lack of oxygen, organic matter, and high Fe : Mn ratio in the soil are the factors causing red skin (Xiao et al., 1987). Rusty root is common in some ginseng-growing regions in North America. Pathogens have been isolated from infected roots (Li, 1992a), but it is too early to rule out other factors such as soil type, moisture, temperature, and fertility.

Heat damage and papery leaf. This disorder is caused by insufficient shade or water deficiency (Whetzel and Rosenbaum, 1912). Initially, leaf blades become light brown and papery, and finally wilt and/or die (Nakata and Takimoto, 1922, Parke and Shotwell, 1989, Xiao et al., 1987).

Unbalanced soil fertility and soil moisture. Unbalanced soil fertility will enhance the occurrence of ginseng diseases or disorders (Chase and Poole, 1986; Lee et al., 1990; Li, 1992b; Parke and Shotwell, 1989). High salt levels in the soil cause injury to plants, especially seedlings. High or low soil pH will affect the availability of soil nutrients, which, in turn, may cause nutrient deficiencies (Persons, 1986).

Infectious disorders

One of the most common diseases affecting Asian and American ginseng is damping-off caused by *Rhizoctonia solani*, *Fusarium* spp., *Pythium*, and *Phytophthora* (Bunkina, 1957; Parke and Shotwell, 1989; Whetzel and Rosenbaum, 1912). In China, it was reported that damping off is caused by *Pythium debaryanum* (Choi and Chung, 1971; Liu, 1988). Other common diseases are leaf blight caused by *Alternaria panax* (Bunkina, 1957; Buonassissi and MacDonald, 1990; Lee et al., 1990; Rosenbaum and Zinssmeister, 1915; Whetzel and Rankin, 1909) and root rots caused by *Phytophthora cactorum*, *Rhizoctonia solani* (Bunkina, 1957; Hori, 1907; Rosenbaum, 1915; VanHook, 1906), *Sclerotinia libertiana* or *Stromatinia libertiana* (Latysheva and Sevryuk, 1981), *Fusarium solani* (Cheon and

Kim, 1990; Chung et al., 1984; Yu, 1987), *Cylindrocarpon destructans* (Hildeband, 1935; Li, 1992a; Parke and Shotwell, 1989; Yu, 1987), or *C. panacicola* (Hildeband, 1935, Liu, 1988, Xiao et al., 1987).

In Korea, farmers prefer to practice disease prevention rather than disease control. Their recommendations are: 1) remove and burn the dried leaves; 2) in the fall, remove thatch shades and place on top of the soil bed to prevent soil moisture increases from rainfall; 3) select only good healthy seedlings for transplanted; and 4) spray the ginseng garden three times a year with Bordeaux mixture as follows: 20 May–10 June, 0.8% concentration; 10–30 June, 1% concentration; 30 June–10 July, 1 % concentration (Liu, 1988).

Replant disease. Replant disease is a complex problem caused by either physiological disorders or infectious microorganisms. According to the literature, ginseng cannot be replanted to the same site due to infectious diseases, low organic matter, soil compaction, and unbalanced nutrients (Xiao et al., 1987), which cause high mortality rate and low yield (Whetzel and Rosenbaum, 1912). Replant soil has more diseases related to too high N levels, low C : N ratio, reduced P, unbalanced N–P–K ratio, and low levels of micronutrients such as B, Zn, Mn, and Fe (Xiao et al., 1987).

To reduce replant problems, crop rotation, fertilizer application based on soil testing, and soil fumigation are recommended. A disadvantage of soil fumigation is that it also affects beneficial microorganisms. Some fields respond well to fumigation, with 80% plant survival rate in the first year, but disease may increase dramatically in the second year. Nevertheless, soil fumigation with formaldehyde or steam-sterilization is still beneficial compared to nonfumigated fields (Whetzel and Rosenbaum, 1912). Based on greenhouse experiments, Li (1994) pointed out the potential of chemical and nonchemical treatments for controlling ginseng replant disease.

After-harvest procedures and value-added products

In Korea, roots are graded based on their shape and size and categorized for processing to make red ginseng and for drying to make white ginseng. The best grade (10 to 35 cm long, 1 to 4 cm in diameter, two to

three side branches, and weighing more than 60 g) is used for making red ginseng by steaming the roots before drying (Hahn, 1978). Ginseng roots that are not used for red ginseng, but are better than process grade, are classified as white ginseng. After drying, these roots can be divided into four groups based on weight. The roots are sliced and divided into 10 classes based on the number of pieces per 60-g bag (first class is 15 slices, followed by 20, 30, 50, 60, 80, 90, 120, 160, and above 160). Slices are packaged in boxes with 10 bags in each box.

Recently, guidelines were introduced in China for handling ginseng after harvesting. Controlled-atmosphere storage is recommended. Dry roots should contain 11% to 13% moisture. During storage, roots may absorb moisture from the air and initiate enzyme reactions that will reduce the effectiveness of ginsenosides in the roots. Use of cobalt 60 radiation on the roots before drying is recommended to eliminate microorganisms, insect eggs, and larvae and to prevent loss of ginsenosides. Use of a microwave oven to heat fresh roots will shorten the drying period. Freeze-drying methods also are suggested (Liu, 1988).

Ginseng powder from roots can be sold in the form of tablets and capsules. There are many value-added products from ginseng, such as ginseng wine, tea, gum, candy, royal jelly, honey, cigarette, drinks, etc. Experiments are underway with very promising results at Summerland, B. C., for modified-atmosphere packaging of ginseng roots to be sold fresh in the winter. An interesting value-added product was created recently in China—canning small ginseng roots in syrup. Total ginsenosides in this product are 5.6%, compared to 4.3% in red ginseng and 5.2% in white ginseng (Xiao et al., 1987).

Ginseng leaves can be picked just before harvest, usually in the middle of September, for extracting the ginsenosides and for other processing purposes. Dried young leaves also can be used as tea. Ginseng flowers are highly valued products with high ginsenoside contents. Ginseng flowers and flower buds saved during flower thinning can be used as tea additives or mixed with brown sugar as ginseng stimulants.

Rhizomes can be steamed and

soaked in syrup (honey ginseng) and sold as an emetic (Hahn, 1978). In preparing sugar or honey ginseng, the syrup in which the roots are soaked contains constituents of ginseng. This residual syrup can be condensed and cut into squares and sold as ginseng candy or used as tonics. During the process of making red ginseng, the liquid that drops off from the steamed roots falls into the water of a steamer. This water can be collected and used for making ginseng paste for tonics.

Conclusion

Once-secretive information regarding cultural methods of ginseng is gradually becoming available for growers and researchers around the world. Growers in North America are starting to question the information from Asia that they have been following for many years. Researchers are trying to improve the Asian techniques and apply them to the expanding North American ginseng industry. As Confucius once said, any person will benefit from studying existing knowledge before learning something new. This is certainly true in ginseng research.

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