Production Practices for North American Ginseng: Challenges and Opportunities

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Abstract

North American ginseng production may have been maximized in the traditional growing areas in the last decade and further increases may be in woods grown root, for niche markets. The marketplace demands high quality roots. Most problems leading to low quality roots start with the grower and can be avoided. These include poor site selection, inadequate soil drainage, untimely and poorly applied pesticides, and neglect of good sanitary practices. Selection of low lying sites increased the plant damage from frost in Ontario in May 2002.

Seeding is still the major method of propagation of ginseng in spite of some success in culturing different parts of the plant. Opportunities exist for shortening the stratification period of North American ginseng seed to allow spring planting. This may reduce disease incidence. Since only one-third of ginseng seed sown ultimately produces plants harvested after 3 years any approach that reduces disease incidence and improves seed germination, seedling emergence and crop stand must be pursued.

Disease is the major problem in ginseng cutivation from seed stratification, soil preparation prior to planting, right through to drying of the roots. Replant disease remains as an unresolved problem and needs full characterization and new approaches for control. Much progress has been made in research and related extension activities in disease control although challenges will arise such as with Quintozene and its replacement with Quadris for control of diseases caused by *Rhizoctonia*.

Decreased labor populations and increased associated costs for ginseng production are causing rapid mechanization in every aspect of the ginseng industry. Engineers, machinery dealers, and fabricators, and growers are being challenged to increase efficiency by mechanization.

Introduction

All phases of ginseng cultivation practices are being questioned in North America. Most of the traditional wooden lath shade has been replaced by black polypropylene shade and every aspect of production from seeding to harvesting and drying is being evaluated for increasing efficiency. Traditional labor sources are vanishing so increased mechanization and practices are being assessed. As production methods change, increasing attention is being given to environmental concerns about pesticides and fertilizers. Nutrient management plans are being drafted and will be legislated. The ginseng production system in the next decade will include an integration of horticultural, biotechnological, and agrochemical methods in an acceptable economic package that optimizes root quantity and quality and safeguards the environment.

All of the above is happening at the same time as a rapid rise in phytopharmaceutical consumption. According to the Canadian Pharmaceutical Association, the Canadian herbal medicine market was valued at $150 million in 1995 and was growing at an annual rate of 15%. A 2000 survey showed that 50% of Canadians have used herbal medicines. As well, according to the American Pharmaceutical Association, more than one third of Americans are using herbs for health purposes, and 2001 saw sales in this area of $4 billion (Molyneaux, 2002).

The following topics were chosen to highlight some of the changes in North American ginseng cultivation as we move into a new production and marketing era in a new century.

Production and Trade

Estimates of ginseng production in major centers around the world are difficult to locate and even if found, reconciliation between sources is often difficult. World ginseng production has doubled since the mid 1980's. Since then South Korean production increased to about 5000 t and has remained around this figure. Chinese production is also estimated at 5000 t. Annual production figures often reflect growing conditions for the crop, particularly the incidence of disease rather than change in crop area.

In Canada, ginseng production has increased steadily. Production in 2000 was about 2000 t with Ontario accounting for 70% of the crop. In Wisconsin U.S.A., production was 450 t in 2000 and has been declining since 1995 when it produced 1000 t.

The major unknown in world ginseng is Chinese production and its marketing. One development in China has been to grow North American Ginseng, known in China as Wulong ginseng for local markets to replace costly imports, and also possibly export (Wang et al., 1995). The project was initiated in 1975 and after much research and development, production is estimated at 200 t.

Hong Kong continues to be a major importer, distributor, processor, and retailer of ginseng (But et al., 1995; Evans, 1995). Over 80% of American ginseng grown in North America is shipped to the Hong Kong market as is much of the Oriental ginseng from China and Korea. Redistribution of ginseng from Hong Kong is world-wide with major destinations being Taiwan, Japan, Malaysia, Singapore, and the U.S. Hong Kong has become a major center for ginseng trade because of a strong herb industry, a large population of Chinese origin, its strategic location, and a strong finance and communication system. In addition, Hong Kong has become a center for scientific research into Chinese traditional medicine and cures (Evans, 1995). The Chinese University of Hong Kong is helping to integrate Chinese and Western techniques and approaches to testing traditional medicines and cures. Ginseng is included in these studies.

There has been a strong European market for ginseng since its introduction by Pharmaton SA in the 1960s. Well established markets are in Scandinavia, Poland, Germany, Spain, Holland, Belgium, the UK, France and Italy. The Eastern European countries, which already have a strong herb and medicinal plant industry, are projected to be receptive to ginseng.

Cultivation of North American ginseng is also being attempted in Australia (Baxter et al., 1995) and New Zealand (Follett et al., 1995). Ginseng use in oceania is likely to rise because of increasing immigration from South East Asian countries and demand for natural medicines. Since imported ginseng is used to meet market demands, domestic production, and a move to agricultural diversification are stimulating interest in ginseng.

Growing Methods

Most ginseng in North America is grown using field cultivation techniques. Although production practices may vary between regions (Ontario and British Columbia, Canada, and Wisconsin, U.S.A.) the basic principles within North America, and indeed around the world, are similar. As the native environment of ginseng is in the understory of deciduous forests of eastern Asia and North America, simulation of this environment is necessary (Stathers and Bailey, 1986). An elevated shade canopy and a surface covering of organic mulch are used to achieve this environment.

The basic climate requirements, and the macroclimate modifications, for ginseng crop production have been summarized (Proctor, 1980; Proctor, 1988). These include; (i) solar radiation, and its modification for ginseng; (ii) root environment (considerations of soil physical structure and nutrient and moisture availability, aeration) that affect ginseng growth; and (iii) freedom from climatic conditions conductive to the spread of diseases and insects. All these conditions are met by production systems employed.

1. There are a number of ways that ginseng grows, or is cultivated, including:

2. Wild ginseng that grows naturally in the understorey of deciduous hardwood or mixed-wood forests.

3. Wild-simulated ginseng growing in which seeds are sown thinly in the forest environment and left to grow naturally so that highly desirable roots, similar to roots of wild ginseng, are produced.

4. Woods cultivated ginseng in which the natural forest canopy is used for shade and raised growing beds are formed.

5. Production on mulched raised beds under artificial shade.

6. Tissue cultured root.

Artificial shade growing is the most common cultivation method world wide (Proctor, 1996; Proctor et al., 1988). Woods growing (woods cultivated and wild simulated) accounted for about 4% of total U.S. ginseng production in 1994 and 9% in 2000 (Persons, 1995; Persons, 2000). This increase reflects a decline in field production under artificial shade and increased planting in the woods. Roots of woods grown plants provide a high quality product for an expanding niche market.

Authoritative guides or bulletins on ginseng production and diseases, particularly for North American, have been published e.g. Parke and Shotwell, 1989; Brammall and Fisher, 1993; Oliver, 1998; Ontario Ministry of Agriculture, Food and Rural Affairs, 2001; Reeleder and Fisher, 1995a, b. The book "Canadian Medicinal Crops" (Small and Catling, 1999) has an excellent 6-page chapter on ginseng including many world wide web links. An illustrated compendium, *Diseases and Pests of Vegetable Crops in Canada* (Howard et al., 1994) includes discussion of 8 fungal diseases, 3 insect pests, 3 nutritional and other disorders, and nematodes and slugs in ginseng. The Proceedings of the North American Conference "American ginseng production in the 21st century" is an extensive coverage of all things related to ginseng production with an emphasis on wild-growing, -simulation, and woods cultivation (Beyfuss, 2000).

Spring frosts can damage ginseng resulting in puckered leaves, death of leaflets, or even whole plants (Oliver, 1998). In Ontario, in April 2002, warm air temperatures and timely rainfall caused ginseng to emerge. Around May 20th air temperatures fell below zero C on 3 to 5 nights with some temperatures as low as –10°C. An estimated 78% of growers reported damage ranging from severe to light (www.ginsenggrowers.com). Similar damage to the Ontario crop has not been reported in the last 75 years. Damage varied across the growing region and within farms and, was most severe in low lying areas.

If seedling plants were damaged they died and will not recover as no perennating bud was formed. Damage to 2-year-old and older plants included puckered and wilted leaves turning black, swollen and burst stems leading to toppled plants, swollen peduncles and shriveled inflorescences. These damaged plants will re-grow next year but the impact on yield this year and in subsequent years is difficult to predict. Disease control measures have been increased as Botrytis has developed beneath the canopy on frost-damaged stems and inflorescences. Also, Alternaria has moved into gardens where there is a past history of that disease.

Seed and Seeding

Seeding is still the principal method of propagating ginseng yet little is known about seed after-ripening, stratification, and germination particularly for North American ginseng (Proctor and Bailey, 1987). In North America ginseng seeds are after-ripened in stratification beds outdoors after they are collected in Aug/Sept. (Polczinski, 1982). They will not grow until the second spring following harvest (18-22 months). Oriental ginseng can be germinated and induced to grow in 8 to 10 months (Proctor et al., 1990). If American ginseng seed could be manipulated like Oriental then spring planting would be feasible. The establishment of ginseng plantings in the spring, instead of the traditional fall period, could offer advantages particularly in relation to reduction in damping-off and root rot diseases (Gotlieb, 1981). Disease is the limiting factor in ginseng production (Parke and Shotwell, 1989; Proctor and Bailey, 1987) because it reduces the stand of ginseng seedlings, the productive life of the ginseng planting, and the number, size, and quality of marketable roots.

A number of problems in North American ginseng stand establishment have been linked to the seed stratification procedure. For instance, Proctor and Louttit (1995) reported premature seed germination (up to 10%) in the seed box after only 8 months of stratification, a condition likely due to fluctuating temperatures. These premature seedlings die and associated fungi may infect other seed in the box. Also, ginseng seed harbor pathogenic fungi and seed can be colonized during stratification despite fungicidal treatment of seed (Tianyi and Weiqun, 1992; Ziezold et al., 1998c). Seepage of water from adjacent soil into stratification boxes may introduce unwanted fungi. Because of these problems stratification of ginseng under controlled-temperature conditions and above-ground has been suggested as a viable alternative.

Indoor controlled-temperature stratification of North American ginseng seed is an acceptable alternative to traditional outdoor, in-ground stratification as it allows control over the environment, easier seed handling, avoids premature seed germination and may have application in spring seeding (Proctor et al., 2000).

The establishment of ginseng gardens in the spring has been difficult because of the inability to store stratified seed from fall to spring. We have been able to stratify and germinate "green" (Aug. harvested) seed in the following May very successfully in the greenhouse (80%-100% germination) but with limited success in the field (30-40% germination). We have used a combination of seed treatment regimes and growth regulators, particularly gibberellic acid, to achieve this early stratification and germination. We propose to refine our earlier work so that spring planting is a viable and profitable production system and an alternative to fall planting (Hovius et al., 1995).

There are many aspects of ginseng seed stratification that have not been investigated but which probably influence germination, seedling emergence and crop stand. For instance, there have been no studies on ginseng seed development in the umbel in relation to germination. In other plants with an umbellate inflorescence such as carrot, variability in seedling weight at emergence is associated with variation in embryo length, which is influenced by umbel order and the date of harvest (Gray and Steckel, 1983).

Tissue Culture, Propagation and Biotechnology

An efficient tissue culture regeneration system may be an alternative to seeding. Such a system would allow rapid propagation of genotypically superior lines of ginseng and could reduce the inherent variability associated with plants derived from seed (Bai et al., 1997; Boehm et al., 1999). Also, *in vitro* plantlet regeneration could allow manipulation of the genetic make-up of the plant and development of transgenic plants expressing novel traits such as disease resistance and increased ginsenoside content.

Brown et al., (2001) have reported a 9-stage protocol for micropropagation of North American ginseng using somatic embryogenesis and mutiple shoot formation. The early stages of the protocol were efficient (90-95%), but latter stages were less successful with only a 3% overwintering efficiency. Production of high quality root formation on the tissue culture derived shoots seems to be the limiting step.

Early attempts to tissue culture ginseng from various tissues were reviewed by Proctor and Bailey (1987). The three reports for American ginseng were of root cultures producing callus, embryonic calli and plantlets (Wang, 1990), of leaf and root explants giving somatic embryos (Tirojah et al., 1998) and of somatic embryos from cotyledons, zygotic embryos and shoot explants (Wang et al., 1999a). Although considerable progress has been made much more research and development is needed before tissue culture regeneration systems can replace seeding.

The *in vitro* culture of North American ginseng cells or tissue for the production of ginsenosides has not been reported. For ginsenoside production from ginseng cell cultures to be commercially successful large amounts of ginsenosides must be produced rapidly. Wang et al., (1999b) showed that somatic embryo-derived plantlets produced ginsenosides, but in lower amounts than field-grown plants. They suggested that ginsenoside production is correlated to the degree of tissue differentiation. Plant cell culture for ginsenosides may have a place in production of these metabolites for inclusion in value-added products. It will complement field culture of roots rather than replace it since consumer preference is for whole roots.

Chen and Punja (2002) have reported the first *Agrobacterium*-mediated transformation of North American ginseng that achieved the integration and expression of a chitinase transgene in calli and regenerated plantlets. This achievement has the potential to enhance the tolerance of North American ginseng to fungal diseases.

Inflorescence/Flower Removal

Little is known about fruit set and development in ginseng (Proctor and Bailey, 1987). In commercial practice a small proportion of 2-year-old plants may bear flowers and seed, but the seeds usually are not harvested. Seeds from 3-year-old plants can be used for establishing plantings, but those from 4-year-old plants, are preferred when available. Some growers remove flowers manually from plants in June at an estimated cost of $2500/ha and claim higher root yields. Others allow the seed and root to develop simultaneously. In some crops, e.g. potato (*Solanum tuberosum* L.), flowering and fruiting depress tuber yield in some years but not others, (Bartholdi, 1942; Proudfoot, 1965), or have variable effects depending on environmental conditions (Jansky and Thompson, 1990).

Proctor et al., (1999) showed that manual removal of inflorescences from mature (3-and-4-year-old) American ginseng plants at commercial timing (early July, ~25% flowers open) increased root yield at harvest. Consecutive inflorescence removal for 2 years (3rd and 4th) increased yield 55.6%. Inflorescence removal in 4-year-old plants increased yield by 34.7% compared with 26.1% in 3-year-old plants. Analysis showed that the largest percentage of roots (~40%) was in the medium category (10-20 g) and inflorescence removal did not influence root size distribution. Root yield for 3-year-old plants increased quadratically with plant density, with plants lacking inflorescences having an estimated yield incrase of 25%. Maximum yields of 2.4 $kg \cdot m^{-2}$ for deflowered plants were achieved at a plant density of 170 plants/m^2. To maximize ginseng root yield, all plants except those needed to provide seed for future plantings should have inflorescences removed.

As North American ginseng production has expanded rapidly in the last decade, returns on investment have decreased as production costs increased. To remain profitable growers need to use new integrated management approaches. These approaches will include reduced pesticide use for disease control and replacement of hand labor with other less expensive methods. For instance, as seed prices decline (Proctor et al., 1999) manual inflorescence removal at $2500 per hectare may be replaced with an inexpensive method in 2-, 3- and 4-year-old ginseng. Proctor et al., (1999) showed that manual inforescence removal in 3-year-old ginseng increased root yield by 26%.

We have screened plant growth regulators (PGRs) for flower removal in ginseng. Some compounds, e.g. thidiazuron, were ineffective in flower removal, but thickened roots, induced adventitious buds in the roots and increased root yield (Proctor et al., 1996). Of the PGRs screened, ethephon showed promise for removing flowers in ginseng.

Ethrel contains 240g/L of the active ingredient, ethephon, which is commonly used for accelerated and uniform fruit ripening and fruit loosening for easier harvesting. Ethephon results in the production of ethylene, a gaseous plant growth regulator, which speeds up the ripening process. Chemical removal of flowers will only be found effective if there is little damage to the plant so that any induced senescence does not limit root growth. Threshold levels used for determining the effectiveness of the various compounds tested by us were "at least 75% removal of berries and no more than 25% damage to the foliage".

Varying concentrations of ethephon were applied to 3-year-old ginseng plants in fields of southern Ontario (Fiebig, 1999). We studied the effects of this chemical by observing plant health and berry removal abilities after treatments were applied, and root weight comparisons between the different treatments at the end of the season. All treatments were ultimately compared to the practice of manual removal. We found that the highest concentrations of ethephon gave the best rates of flower removal, but also caused the highest amount of foliar damage to the plants. The lowest concentrations, on the other hand, did not provide good enough rates of berry removal even though these plants were the healthiest. When all things were considered, a mid-range concentration of 5L/Acre Ethrel resulted in the highest level of berry removal and consequently the greatest root weight. It was found that removal of ginseng flowers increased 3-year-old root yields by as much as 30%.

Pest Control

Disease control remains the central problem in commercial cultivation of ginseng globally. As early as 1930 Whetzel et al., reported that the average yield of ginseng in the United States was one-sixth to one-third of expected because of the numerous diseases that attack the crop. Ohh (1986) has quantified losses from diseases in Korea as follows: anthracnose (20-47%), damping off (5-50%), root rot (1-60%), phytophthora (2-30%), and alternaria blight (10-20%).

Globally, the commercial cultivation of ginseng requires the application of registered pesticides. Pesticide evalution and registration is on-going.

Diseases caused by *Cylindrocarpon destructans* and *Rhizoctonia solani* have been receiving increased attention recently because of their severity and lack of control measures. Ziezold et al., (1998a, 1998b, and 1998c) have evaluated soil drenches, fungicides *in vitro* and seed treatments for control of *Cylindrocarpon destructans*.

In Canada, Quintozene (PCHB) has been registered since 1990 for control of damping off, bud and stem rot caused by *Rhizoctonia* sp. Continued use of Quintozene is being questioned because disease control has been inconsistent, residue problems have arisen and marketing opportunities have been restricted (Littley, 2000). This has necessitated the replacement of Quintozene with

Quadris (azoxystrobin). The fungicide Elevate [R] [fenhexamid] (www.arvesta.com) has been registered in Canada in 2002 to combat recurring problems in Botrytis control, particularly in frost damaged plants.

Rusty root in ginseng is a problem worldwide. Orange colored spots on ginseng roots are called rusty root (OMAFRA, 2001; Parke and Shotwell, 1989) and reduce root quality. Losses from rusty root in Ontario in 2001 were estimated at $30 million. Presently there are no control recommendations for rusty root. The cause of rusty root is either a physiological stress and/or a disease (likely caused by *Cylindrocarpon destructans*). The cause(s) of rusty root must be determined and appropriate control measures that will reduce its incidence must be developed.

Mechanization

Ginseng production is extremely labor intensive. Also, labor supply and cost are major factors in the effciency and optimization of ginseng production. Therefore, increased mechanization in ginseng production is receiving international attention (Mok et al., 1993; Oliver, 1998; van Dalfsen et al., 1993).

In the establishment of ginseng gardens bed plows and bed groomers are used extensively and are now fairly standard throughout the North American industry. Hydraulic post presses are replacing post pounders. The sowing of seed has progressed rapidly in the last decade. The one-row, hand-held Planet Junior which gave both a crude-sizing capability and a spreading device that produced scattering of the seed to reduce bunching has been replaced with tractor mounted multiple-row seeders. Although these units allow seeding of 2 ha or more per day there is still an opportunity to improve plant stand and final root quality using sized seed and precision seeding. Subsoiling to overcome soil compaction, improve water drainage and improve soil structure has become more common.

The traditional wood lathe shade system is rapidly being replaced by plastic shade systems. The plastic system requires fewer shade support posts thus allowing fewer and wider passes with the sprayer and fewer posts to purchase and install. Possibly all artificial shade for ginseng growing will be plastic in the near future.

Irrigation is essential at seeding time, to maintain soil moisture during the growing season, particularly in arid areas, and to overcome heat stress. Many systems are available for applying irrigation water (Oliver, 1998).

Many different types of sprayers are used. The most common type uses a hydraulic boom; sophisticated sprayers have large spray tanks and complete hydraulic drive systems in self-propelled units.

The objective in root harvest and post-harvest is to mechanize the complete process. The most advanced diggers convey the root into bulk bins. These bulk bins can be moved with fork lifts to cold storage or processing lines.

Cold storages are often used to store roots at 1 to 5°C for up to 6 weeks after harvest when dryer space is at a premium. These same cold storages can be used for indoor, controlled-temperature stratification of seed (Proctor et al., 2000)

At the processing lines the bulk bins are mechanically dumped for root washing, inspection, and loading onto dryer trays. These dryer trays can be moved mechanically into dryers. Most ginseng dryers in North America are modified tobacco kilns with the necessary technology being taken from the tobacco industry. After drying, the roots are inspected again and loaded into drums with automatic weight recording. The system described above is the one that all growers should reach within the next decade.

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