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The Adaptation of Ginseng Production of Semi-arid Environments: The Example of British Columbia, Canada

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Abstract□ Ginseng is renowned for both its medicinal and herbal uses and successful cultivation of *Panax ginseng* in Asia and *Panax quinquefolium* in North America has until recently taken place in the native geographical ranges of the plants. As a consequence of the potential high capital return and anticipated increases in consumer consumption, commercial cultivation of American ginseng now occurs well outside the native range of the plant in North America. In fact, the region of greatest expansion of cultivation is in the semi-arid interior region of British Columbia, Canada. Linked with this expansion is the potential domination of the ginseng industry by agricultural corporations.

In the interior of British Columbia, the native decidous forest environment of eastern North America is simulated with elevated polypropylene shade and a surface covering of straw mulch. The architecture of these environments is designed to permit maximium machinery useage and to minimize labour requirements. Further, with only a four year growth cycle, plant densities in the gardens are high. In this hot, semi-arid environment, producers believe they have a competitive advantage over other regions in North America because of the low precipitation rates. This helps to minimize atmospheric humidity such that the conditions for fungal disease development are reduced. If soil moisture levels become limited, supplemental water can be provided by irrigation. The nature of the radiation and energy balance regimes of the shade and much environment promotes high soil moisture levels. Also, the modified environment reduces soil heating. This can result in an aerial environment for the plant that is stressful and a rooting zone environment that is sub-optimal. The challenge of further refining the man modified environment for enhanced plant growth and health still remains.

Keywords□ *Panax ginseng, Panax quinquefolium,* cultivation, ginseng production.

Introduction

American ginseng (*Panax quinquefolium* L.) has long been recognized as a valuable horticultural crop as a consequence of its root's useage for both herbal and medicinal purposes. Further, as it is viewed by consumers as complimentary to Asian ginseng (*Panax ginseng,* C.A. Meyer),[1] American ginseng production has not been severely impacted by the expanded production of Asian ginseng. Until recently, the production of American ginseng was for the most part controlled and restricted to specific locales in eastern North America (Fig. 1). The largest production areas were principally in Wisconsin, U.S.A. and Ontario, Canada (Fig. 1). In recent years, increases in seed availability has enabled production areas to expand both within the native geographical range of plant as well as beyond its native range.[2]

In 1982, large scale American ginseng production commenced in the interior of British Columbia, Canada. This location is geographically removed and environmentally distinct from the plant's native range. Since that time, production in British Columbia has increased dramatically such that the production area now rivals or exceeds that of some of the traditional production areas. British Columbia has the potential to be the world's largest producer of American ginseng.

Past research on American ginseng in the semi-arid interior of British Columbia has documented the seasonal soil temperature and moisture regi-

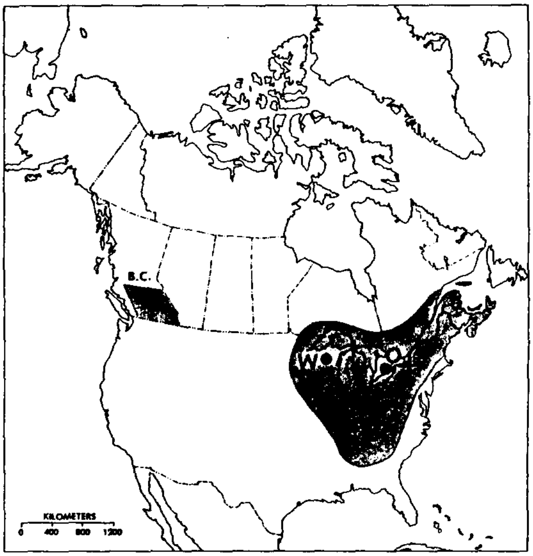

Fig. 1. Map of North America showing the native range of American ginseng (*Panax quinquefolium* L.) in eastern North America. The production areas in Ontario and Wisconsin denoted together with the approximate boundaries of the British Columbia growing region.

mes,[3] the statistical relationships between above and below ground American ginseng plant morphological characteristics[4] and the energy receipts and partitioning within the shade canopy environment.[5] In this paper, three topics that reflect the production of American ginseng in semi-arid environments will be addressed. First, a brief review of the history and present day nature of the ginseng industry in British Columbia will be given. Second, an overview of the environmental resources required for American ginseng production will be considered with particular emphasis given to the adaptation to semi-arid environments. Third, American ginseng root growth for plants aged one to four years inclusive will be considered.

The Ginseng Industry in British Columbia

The early history of American ginseng harvesting, cultivation and marketing has been well documented.[6-9] Whereas the development of the ginseng industry in Ontario and Wisconsin was linked to the harvesting of wild ginseng and the slow development of artificial shade gardens over the past one hundred years, the ginseng industry in British Columbia was born out of the application and adaptation of eastern North American technology to a semi-arid environment.

In the early 1980's, a public company was formed in British Columbia, Canada whose sole purpose was to commercially grow and market American ginseng. The company was named Chai-Na-T Ginseng Products and from that day until the present it has been led by its President, Mr. J.M.M. Latta. Chai-Na-Ta Ginseng Products has expanded dramatically since its first planting of 2 hectares in the autumn of 1982 in the Botanie Valley near Lytton, British Columbia (50° 17'N, 121° 34'W). At the present time, the company grows American ginseng at a number of locales throughout the semi-arid region. The shares in the company are listed and trade on both the Vancouver Stock Exchange and the Toronto Stock Exchange.

Although small plantings of American ginseng had been reported in western North America prior to 1982, Chai-Na-Ta Ginseng Products has played a fundamental and dominant role during the infancy and development of the ginseng industry in British Columbia as a consequence of its initiative and size. As Chai-Na-Ta Ginseng Products is a public company that raised capital through public offerings of shares, other agriculturalists in British Columbia soon became acquainted with the potential profitability of American ginseng cultivation.

The character of the American ginseng industry in British Columbia today reflects the impact of the reapid growth during the years since 1982. As startup costs are high (approximately $CAN 75,000 per hectare) and four years are required before harvest, the high capital demand excludes the participation of many farmers. As such, there currently exists one very large producer (Chai-Na-Ta Ginseng Products is the largest producer in North America) and a number of much smaller growers (Fig. 2). This is very well documented in Table 1 which provides a summary of the size of individual plantings of ginseng in British Columbia from 1982-1989. Be-

Table 1. The size of individual plantings of American ginseng in British Columbia during the period 1982 through 1989.

Planting Size (ha)	DATE 1982	1983	1984	1985	1986	1987	1988	1989
0-0.50	–	–	–	3	9	6	15	5
0.51-1.00	–	–	–	–	–	–	1	1
1.01-2.50	1	1	–	–	–	–	–	2
2.51-5.00	–	–	1	– –	–	–	–	–
5.01-10.00	–	–	–	1	–	–	–	–
10.01-20.00	–	–	–	–	1	1	–	1
20.01-40.00	–	–	–	–	–	–	1	–
40.01-60.00	–	–	–	–	–	–	–	1

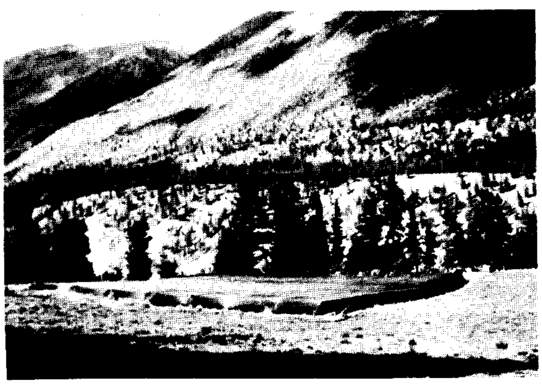

Fig. 2. Photograph illustrating a small commercial planting of American ginseng in British Columbia. The planting is 0.4 hectares in area andd is located near Lillooet.

Fig. 3. Photograph illustrating a large scale commerical planting of American ginseng in British Columbia. This farm has approximately 75 hectares of American ginseng under shade canolpy and is located between Lytton and Lillooet.

tween 1982 and 1984, Chai-Na-Ta Ginseng Products had the only plantings. From 1984 to 1989, the company's expansion each year has been rapid (Fig. 3). It should also be pointed out that the other large planting in 1989 (in the 10.01 to 20.00 hectare range) is linked to Chai-Na-Ta Ginseng Products. At the present time, it is estimated that the total area in production in British Columbia exceeds 130 hectares.

The traditional production areas in Ontario and Wisconsin have faced numerous challenges over the past number of years. Not the least of these has been the higher incidence and severity of plant diseases. Given that British Columbia is not within the native range of American ginseng, and that the British Columbia industry is still in its infancy, many producers believe that they have an advantage over the traditional growing areas. Further, given the semi-arid climate of the interior of British Columbia with low growing season precipitation and low atmospheric humidity values, the potential for disease is substantially less. At the present time, the British Columbia ginseng industry remains linked with the traditional growing areas of eastern North America. However, in the near future, the British Columbia industry may become independent. The timing and nature of this will be fundamentally linked to the management decisions of the largest producer. For many of the smaller producers, the traditional areas will remain as import sources for both seed and technology.

As a consequence of the potential financial returns from American ginseng production, a number of other individuals and corporations have considered entry into large scale production in recent years. To date only one has commenced active operation. Columbia Ginseng Corp. plans to plant 20 hectares of American ginseng each year starting in the autumn of 1990. To do this, Columbia Ginseng Corp. raised funds from a public share offering that had attractive tax credits associated with it. The potential for others to enter the industry exists if seed sources can be secured. Further, given the high startup costs, large scale production in the future will probably be restricted to corporate and joint venture undertakings.

In 1986, a growers organization, the Associated Ginseng Growers of British Columbia, was formed. Since that time the organization has hosted annual seminars as well as sponsored a research program on the marketing of British Columbia ginseng.[10] The Provincial Government of British Columbia has participated through funding as well as by creating a position for a provincial ginseng specialist and by preparing of a grower's guide.[11] Future efforts in British Columbia will likely be directed towards the improvement of production technology, such as the maximization of yield and the minimization of costs, as well as marketing aspects.

Environmental Resources for Ginseng Production

Successful American ginseng production necessitates that there be appropriate climate and soil resources. As the native environment of American ginseng is as an understorey component of deciduous forests of eastern North America, the necessity arises for the simulation of this environment. This has been accomplished through the use of an elevated shade canopy and a surface covering of organic mulch (Fig. 4). Much of the shade used in Ontario and Wisconsin is wood lath with some polypropylene fabric being introduced in the past ten years.[12,13] In British Columbia, most of the shade is black polypropylene fabric (Fig. 4) which transmits

Fig. 4. Photograph of an American ginseng garden taken from beneath the shade canoly. Evident the photograph are the shade canopy, the supporting posts, the raised beds, the straw mulch and the second year American ginseng plants. Also clearly evident is the supply system for irrigation water.

about 22 percent of the incident global solar radiation.

The basic climate requirements for American ginseng crop production have been summarized by Proctor.[12] These include adequate global solar radiation for photosynthesis, adequate water for the solution and uptake of nutrients from the soil, the freedom from climate hazards that produce physical damage and the freedom from climatic conditions conducive to the spread of disease and insects.

The interior of British Columbia lies within the Cordilleran climatic region of Canada[14] and is characterized by hot, dry summers. The winters are the most variable season and are influenced by the eastward progression of Pacific disturbances. Hare and Thomas[14] have recognized the climate of the Lytton area to be near desert-like in the summer. Table 2 provides a comparison of global solar radiation and total bright sunshine data for the growing areas of British Columbia and southern Ontario. As measurements of global solar radiation are sparse, data for Summerland, British Columbia and Guelph, Ontario are used for this purpose. It is noted that the mean daily solar radiation values during the growing season months of April through September are quite similar. The slightly higher annual average values for Guelph arise as a consequence of

Table 2. Global solar radiation[1] and total bright sunshine[2] data for Summerland, British Columbia and Guelph, Ontario

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
(a) Mean daily global solar radiation ($MJm^{-2}d^{-1}$):													Average
Summerland	3.44	6.48	11.54	16.66	20.82	22.64	23.68	19.55	14.47	8.45	3.82	2.50	12.87
Guelph	6.00	10.21	13.32	16.32	20.26	22.72	22.08	19.02	13.98	9.32	4.88	4.49	13.57
(b) Monthly total bright sunshine (hours):													Total
Summerland	49.1	83.6	148.9	198.7	249.8	261.7	320.6	277.1	206.4	140.6	63.6	39.8	2039.9
Guelph	89.1	105.2	134.7	171.6	232.8	250.9	287.6	254.0	173.9	141.4	75.9	70.1	1987.7

Source:
1. Environment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 1-Solar Radiation, 1982.
2. Environment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 7-Bright Sunshine, 1982.

Guelph's more southerly location and the associated higher global solar radiation values during the winter season. The role of the daylight period length is evident for the total bright sunshine data. However, annual tòtals are quite similar. Table 3 provides a summary of temperature, precipitation, soil temperature and degree days data for Lytton, British Columbia and Simcoe, Ontario. Included for comparative purposes are data for Wausau, Wisconsin, U.S.A. and Seoul, Korea. These locations are representative of the major production areas in British Columbia and Ontario, Canada, and the United States and Asia. The temperature data illustrate that Lytton, British Columbia has a warmer regime than that of either Simcoe or Wausau. This is emphasized on a month to month basis for maximum, minimum and mean temperature as well as for annual averages. It should be noted, however, that the temperatures for Seoul exceed even those of Lytton during the growing season and on an annual basis. As expected, soil temperatures and degree days above 5°C will be greater in the interior of British Columbia than for southern Ontario. It is also apparent from Table 3 that Lytton receives less than approximately one-half the precipitation of either Simcoe or Wausau. Also evident is the feature that the summers are very dry. When comparison is made with Seoul, It is noted that Lytton has approximately one-third the annual total precipitation. Whereas the summers at Lytton are very dry, maximum precipitation for the Korean peninsula occurs during the summer period.

Atmospheric temperature and humidity plays a key role in the development, spread and severity of plant disease. From Table 4, it is apparent that for both daytime and nighttime periods that the atmospher at Lytton is much more arid than that for southern Ontario. Given the conditions found in eastern North America of moderate summer precipitation and high atmospheric humidity, it is not surprising that fungal diseases are prevalent. Conversely, the low summer precipitation and the drier atmosphere found at Lytton serves to limit the potential for fungal disease. Table 5 summarizes the frost free period for both Lytton and Simcoe. The approximate one month increase in period length at Lytton has obvious implications for seed germination, plant growth and growing season performance, and crop management.

During the growing season of 1986, field research was conducted in a large planting of two year old American ginseng at Lytton, British Columbia. The following four figures summarize some of the research results. Fig. 5 presents the growing season trends of maximum, minimum and mean daily air temperatures beneath a polypropylene shade canopy. The regime presented is characteristic of that found in gardens of all years of plants as well as in other production areas in British Columbia. It is apparent that the shade canopy did not

Table 3. Temperature[1], precipitation[2], soil temperature[3] and degree days[4] data for Lytton, British Columbia and Simcoe, Ontario. Data for Wausau, Wisconsin, U.S.A.[5] and Seoul, Korea[6] are included for comparative purposes.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
(a) Mean Daily Temperature (C)													Average
i Lytton													
T max	−0.8	5.4	9.9	15.3	20.7	24.0	28.3	27.4	22.6	14.9	5.9	1.9	14.6
T min	−6.9	−2.5	0.2	3.5	8.0	12.3	14.9	14.4	10.3	5.3	−0.7	−4.0	4.6
T mean	−3.8	1.5	5.1	9.3	14.4	18.1	21.6	20.9	16.5	10.1	2.6	−1.0	9.6
ii Simcoe													
T max	−2.4	−1.1	4.1	12.2	18.8	24.6	26.9	25.8	22.0	15.2	7.7	0.8	12.9
T min	−10.3	−10.2	−4.9	1.2	6.4	11.8	14.2	13.2	9.1	3.6	−0.8	−6.7	2.2
T mean	−6.4	−5.6	−0.5	6.6	12.4	18.0	20.4	19.3	15.4	9.2	3.5	−3.1	7.4
iii Wausau													
T max	−6.4	−3.1	2.6	11.9	19.4	24.3	26.8	25.4	20.1	13.9	4.2	−3.2	11.3
T min	−16.8	−14.8	−8.1	0.4	6.6	11.8	14.7	13.5	8.5	3.1	−4.2	−12.1	0.2
T mean	−11.6	−8.9	−2.8	6.2	13.0	18.1	20.8	19.4	14.3	8.5	0.0	−7.6	5.8
iv Seoul													
T mean	−4.9	−1.9	3.6	10.5	16.3	20.8	24.5	25.4	20.3	13.4	6.3	−1.2	11.1
(b) Total Precipitation (mm)													Total
Lytton	76.6	39.4	28.5	18.6	13.0	19.5	11.0	17.0	25.8	37.3	71.4	74.3	432.4
Simcoe	72.5	64.2	85.4	87.3	67.3	71.7	78.3	86.3	81.7	62.6	88.7	88.3	934.3
Wausau	23.6	24.1	48.3	72.6	95.8	99.8	100.8	105.2	98.6	57.4	45.2	31.8	803.1
Seoul	17.1	21.0	55.6	68.1	86.3	169.3	358.0	224.2	142.3	49.2	36.0	32.0	1259.2
(c) Mean Daily Soil Temperature (C) At 0.20 m													Average
Summrland[7]	0.8	0.8	3.8	9.0	14.5	19.0	22.1	22.8	18.0	12.5	6.0	2.2	11.0
Simcoe	0.3	−0.5	0.3	4.9	12.5	18.2	21.3	21.0	17.7	11.5	6.2	1.9	9.6
(d) Degree Days Above 5.0C													Total
Lytton	3.9	17.6	39.0	133.5	290.3	398.9	520.7	496.5	343.1	162.1	28.7	8.6	2442.9
Simcoe	1.0	0.7	12.1	92.7	240.9	393.1	480.1	448.0	318.4	153.7	40.4	4.8	2185.9

Source:
1. Enviroment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 2-Temperature, 1982.
2. Enviroment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 3-Precipitation, 1982.
3. Enviroment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 9-Soil Temperature, Lake Evaporation, Days with...., 1984.
4. Enviroment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 4-Degree Days, 1982.
5. National Climatic Centre, Enviromental Data and information Service, National Oceanic and Atmospheric Administration, *Climate Normals for the U.S.* (Base: 1951-80), 1983.
6. Watts (1969)[18].
7. As the record at Lytton was of insufficient duration, representative data from Summerland, British Columbia are presented.

Table 4. Temperatur and humidity[1] data for Lytton, British Columbia and Simcoe, Ontario.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual Average
(a) Lytton													
0100 LST[2]													
Dry bulb tempurature (C)	-3.9	0.4	2.5	7.0	11.5	15.3	18.1	17.5	13.4	8.2	2.5	-0.9	7.6
Vapour pressure (kPa)	0.42	0.52	0.56	0.68	0.86	1.06	1.23	1.25	1.11	0.86	0.62	0.50	0.81
Relative humidity (%)	80	79	75	69	63	61	60	64	73	79	82	81	72
1300 LST													
Dry bulb tempurature (C)	-1.8	4.1	8.2	13.9	19.8	23.1	26.9	25.4	20.7	13.0	5.3	0.7	13.3
Vapour pressure (kPa)	0.44	0.54	0.56	0.64	0.80	0.98	1.12	1.17	1.03	0.87	0.64	0.51	0.78
Relative humidity (%)	70	63	51	41	36	36	34	38	43	58	69	74	51
(b) Simcoe													
0100 LST													
Dry bulb tempurature (C)	-6.3	-6.3	-1.4	4.1	9.6	15.1	17.2	16.5	13.0	8.0	3.1	-3.3	5.8
Vapour pressure (kPa)	0.35	0.35	0.48	0.67	0.98	1.46	1.71	1.70	1.38	0.96	0.69	0.45	0.93
Relative humidity (%)	81	82	81	77	79	83	85	89	88	85	85	84	83
1300 LST													
Dry bulb tempurature (C)	-4.7	-4.0	2.1	9.7	16.7	22.0	24.6	23.7	19.5	13.1	5.8	-1.4	10.6
Vapour pressure (kPa)	0.3	0.36	0.52	0.73	1.11	1.57	1.80	1.79	1.44	1.01	0.71	0.46	0.99
Relative humidity (%)	76	72	70	59	57	59	58	61	62	65	74	78	66

Source:
1. Environment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 8-Atmospheric Pressure, Temperature, and Humidity, 1984.
2. LST-Local standard time.

Table 5. Frost[1] data for Lytton, British Columbia and Simcoe, Ontario.

	Average Frost free Period (days)	Average Data of Last frost (Spring)	Average Data of First frost (Fall)
Lytton	186	April 20	October 24
Simcoe	155	May 11	October 14

Source:
1. Environment Canada, Atmospheric Environment Service, *Canadian Climate Normals,* 1951-1980, Volume 6-Frost, 1982.

mitigate the cool temperatures of April and May. In fact, frost conditions occurred on many nights during the early part of the growing season. During the period June through early September, daily maximum temperatures often exceeded 30 °C and can approach 40 °C. In September, the seasonal cooling trend is evident. Also presented in Fig. 5 are daily mean soil temperature measurements at a depth of 0.10 m. It is clear that soil temperatures are well below the values of air temperature and that the seasonal soil warming significantly lags that of the seasonal warming of the air. The decrease in global solar radiation caused by the shade canopy and the role of the straw mulch in severely restricting soil surface warming results in low heat transfer into the soil. This has been discussed in greater detail by Stathers and Bailey[5] and Bailey *et al.*[3] It is recognized from the work of Lee *et al.*[15] that the optimum soil temperature for American ginseng root growth is 15-18 °C. It is apparent that this is not characteristic of most of the growing season. In fact, average daily soil temperatures at 0.10 m depth only reach 15 °C in late July. The early and middle parts of the growing season can be characterized as having conditions for root growth that

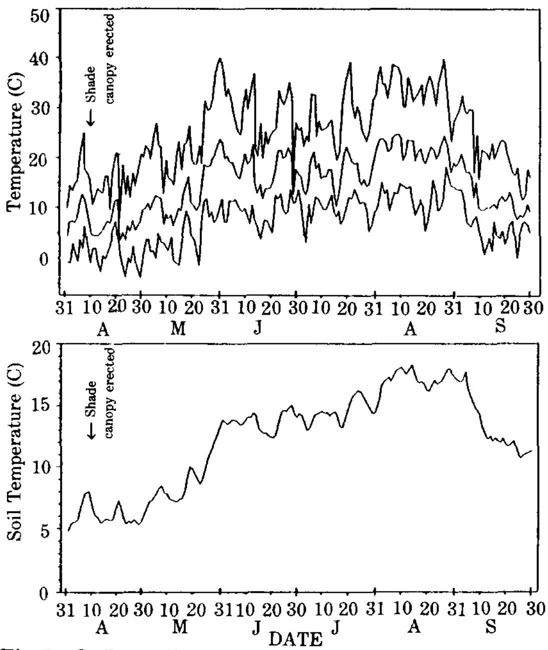

Fig 5. Daily maximum, mean and minimum air temperature beneath the shade canopy and daily mean soil temperature at a depth of 0.10 m for the period Aprill to September 30, 1986 for a second year ginseng garden. For the air temperature data, the upper line denotes daily maximum temperature, the middle line daily mean temperature and the lower line daily minimium tempuratture. The data of shade canopy erection is noted.

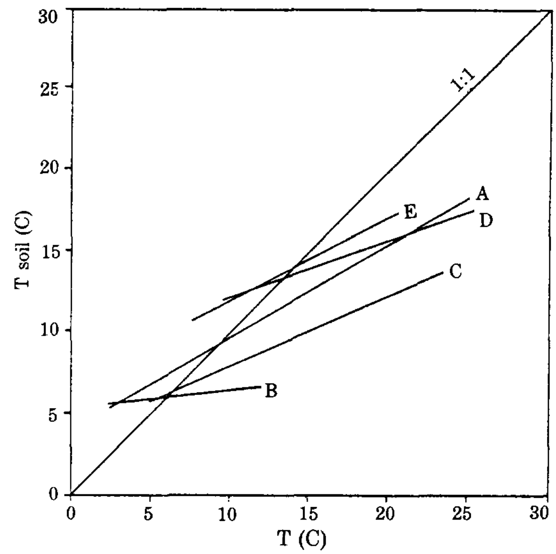

Fig. 6. Relationship between daily mean soil temperature (0.10 m depth) and daily mean air temperature below the shade canopy for the period April 11 through September 30, 1986. Data for the full growing season (A) and for periods during the growing season (B: early eason-April 11-29; C: warming-April 30 to June 5; D: mid-season-June 6 to September 2; E: cooling-September 3-30) are denoted. The 1:1 line denotes the equivalence of air and soil temperatures.

are well below optimum. Fig. 6 demonstrates the relationships between mean daily air temperature beneath the shade canopy and mean daily soil temperature at a depth of 0.10 m for both the full growing season and for four periods during the growing season. The role of the growing season period is apparent together with the characteristic that most days have soil temperatures well below air temperature. Previous research by Bailey *et a*.[3] illustrates that the soil temperatures near the surface in the ginseng garden are directly comparable to those at a depth of one meter in adjacent agricultural surfaces.

The seasonal trend of precipitation and volumetric soil moisture for the second year garden is presented in Fig. 7. During the growing season, only one precipitation event exceeded 10 mm and total precipitation during the growing season was low.

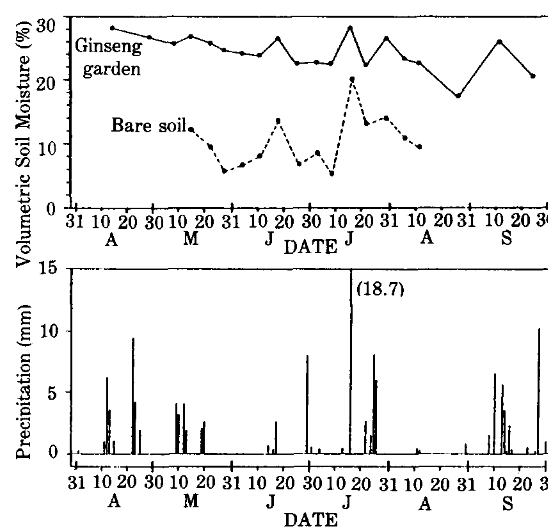

Fig. 7. Growing season precipitation and volumetric soil moisture (0.25 m surface soil layer) for the 1986 growing season. Volumetric soil moisture data is presented for both a second year ginseng garden and a bare soil site.

For this soil, volumetric soil moisture would be considered a limitation on evaporation when it fell below 27.5 percent, equivalent to a matric potential of -33 kPa. The wilting point, equal to a matric potential of -1500 kPa, was found to be equivalent to a volumetric soil moisture of 14.0 percent.[16] For bare soils in this environment, volumetric soil moisture values remain low throughout the growing season. However, in the ginseng garden, volumetric soil moisture remains quite high even though supplemental irrigation was not applied. This clearly demonstrates the feature that the shade canopy and straw mulch are extremely effective at reducing soil moisture loss. When this is coupled with the soil thermal regime, it is apparent that the plant roots will be growing in cool, wet soils. In adjacent areas outside the ginseng garden, the climate is characterized as being near desert-like during the summer months and without the application of irrigation, commercial crop cultivation would not be possible.[16]

Fig. 8 presents a south to north transect of volumetric soil moisture (from the surface to a depth of 250 mm) through a 50 m long ginseng garden. On the south side of the garden, the volumetric soil moisture values in the native pasture and bare soil are quite low. As a consequence of the shade canopy and straw mulch effects, strong horizontal gradients are found at the southern edge of the garden and soil moisture values rise abruptly. Volumetric soil moisture values in the ginseng garden range from 20 percent to greater than 35 percent. The higher values are found with depth and distance from the southern edge of the ginseng garden. At the northern edge of the ginseng garden, the adjustment of volumetric soil moisture to the bare soil surface is extremely abrupt and reflects the strong environmental controls present.

As a consequence of low global solar radiation below the shade canopy, the absolute amount of energy available for partitioning is small.[5] Given the high diffusive resistance of the straw mulch, the potential for evaporation is quite restricted. As such, the dissipation of net radiation into soil heat, latent heat and sensible heat flux densities is dominated by the latter term. As a consequence, plants grown in this environment are subjected to a hot and dry aerial environment but the roots are in cool, wet soil. Acknowledging the work of Lee *et al.*[15], a challenge exists for both researchers and

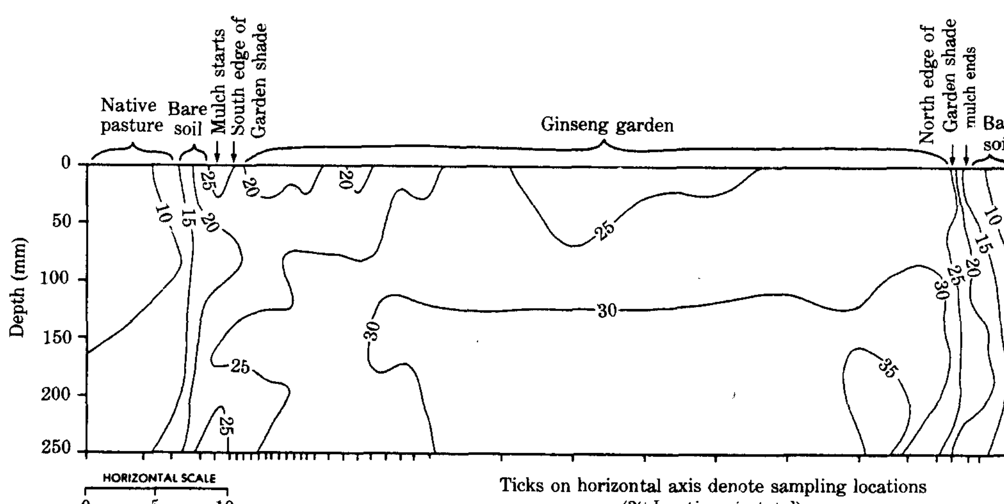

Fig. 8. A schematic diagram detailing a south to north transect of volumetric soil moisture (from the surface to a depth of 250 mm) through a 50 mater long ginseng garden. The location of the ginseng garden, mulch, native pasture and bare soil boundaries are given together with the sample locations. Note that the units for volumetric soil moisture are percentage and that the vertical and horizontal scales are different.

producers to better understand the environmental physics of these growing environments. Emphasis should be given to a further enhancement of the soil environment through garden architecture and crop management practices. This needs to be accomplished without creating a deleterious atmospheric environment.

American Ginseng Root Growth and Development

It is the usual practice to harvest American ginseng roots at the end of the fourth growing season. After the roots are dug from the soil, they are washed and dried. Most of the roots are then sold and exported. Hong Kong is the principal market. As a consequence of the increased incidence and severity of plant disease in the traditional growing areas of Wisconsin and Ontario, it is becoming more common for roots to be harvested at the end of the third growing season. In British Columbia some harvesting of three year old roots occurs but this usually reflects the need for revenue generation rather than as a response to plant disease problems.

Fig. 9 presents the growing season trend of American ginseng root dry matter during the first and second years. It is apparent from this figure that first year root growth starts in June with final root dry matter exceeding 0.1 g per root. In the second year, root dry matter shows an approximate tenfold increase over the duration of growing season. Similar results have been reported by Proctor[13] for Ontario. It is also apparent that in the second year there is a great deal more scatter about the trend. This reflects the commencement of competition for climatic and soil resources as well as the expression of genetic diversity.

Fig. 10 presents root dry matter throughout the growing season for third and fourth year plants. There is considerable scatter about the central trend and evidence of competition for climate and soil resources and genetic diversity exists. As such, the necessity of carefully acknowledging sample size in such investigations is appreciated (Gin *et al.*, 1988).

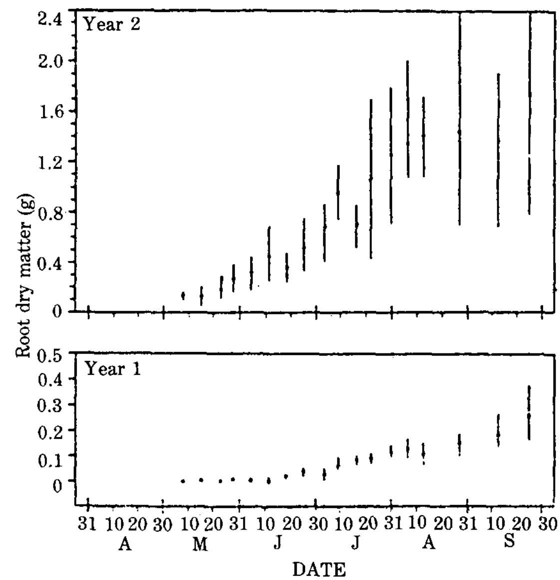

Fig. 9. American ginseng root dry matter for first and second year plants during the 1986 growing season. For each sampling date, five plants were sampled. The mean and upper and lower extremes are presented.

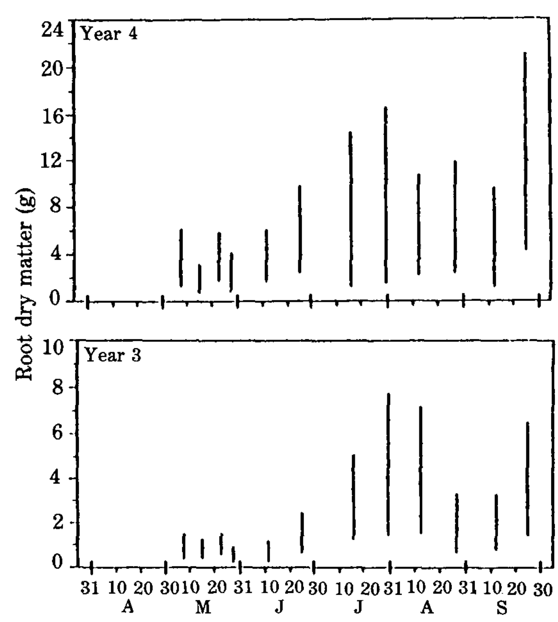

Fig. 10. American ginseng root dry matter for third and fourth year plants during the 1986 growing season. For each sampling date, five plants were sampled. The mean and upper and lower extremes are presented.

In eastern North America, average garden yields are approximately 2,200-2,800 kg per hectare of dry American ginseng root. Production values in British Columbia have been found to consistently exceed these as a consequence of the semi-arid environment and the absence of a long history of ginseng production, both of which serve to minimize the potential, incidence and severity of plant disease. Practical field experience indicates that under the current methods of American ginseng root production, maximum yields will probably have an upper limit of approximately 4,500 kg per hectare. Yields similar to this have been achieved in some of the harvested gardens. It can anticipated that this upper value could be exceeded but these would not be common events or would come from high quality, smaller area plantings. Given the high density of planting generally found in North America, such high yields will consist primarily of smaller sized roots (Gin *et al.*, 1988).

Acknowledging the fact that plant growth is not taking place under optimum conditions, even in this semi-arid environment, the challenge of enhancing the growing environment to yield maximum root growth from optimum plant densities exists. Such challenges likely exist for all of the world's ginseng production areas. It is acknowledged that enhancement must be undertaken through the alteration of the ginseng garden architecture and the management of the ginseng crop without creating aerial environment for the plant which would result in poor growth or plant death.

Summary and Conclusions

Recent experience has shown that American ginseng can be successfully grown in semi-arid environments like those found in British Columbia, Canada. Many proponents of semi-arid environment production believe that such environments provide a potential competitive advantage over traditional growing areas. The absence of a long history of American ginseng production which may contribute to a buildup of plant pests and a more arid environment suggests that disease incidence and severity should be reduced. Further, if precipitation is low and water is required, supplemental water from irrigation can be considered.

The British Columbia ginseng industry developed through the transfer of the technology and seed from eastern North Amerca. The availability of shade cloth and particularly seed are crucial aspects of this dependency on external sources. It can be anticipated that in the future, British Columbia may be able to act as an independent production region. This is conditional and is fully dependent upon the management decision making within the largest ginseng company, Chai-Na-Ta Ginseng Products. It is anticipated that the small growers in British Columbia will increase in number and size of plantings. The absence of plantings between the size of the largest grower and that of the individual small grower will remain a lure for both commercial and joint ventures. In fact, corporate agriculture initiatives may well characterize most of the new production in the future.

The ginseng industry in British Columbia currently rivals or exceeds the area of production in Ontario and it is probabley one-third to one-half of the size of that of Wisconsin. There is every reason to expect that the British Columbia industry will continue its dramatic expansion in area. It may well become the largest producer of American ginseng in North America before the turn of the century. Whether or not the British Columbia industry will be the largest producer in the world will be dependent upon American ginseng production strategies and success in the People's Republic of China.[17] It must be acknowledged that the British Columbia ginseng industry is now fundamentally linked to the world ginseng industry. Future success for the world ginseng industry will be dependent upon further research and development, product development and marketing, and product acceptance by the consumer.

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