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The Micrometeorological Requirements for the Culture of Ginseng (*Panax* sp.)

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Abstract

Ginseng is cultivated in Korea, Japan, China, the Soviet Union and North America. Studies of the macroclimate of each of these producing areas shows that ginseng has certain requirements for production. In each producing area the microclimate is modified in different ways. Comparisons of recent research data from North America, Korea and China is presented in order to define, more precisely, the various microclimate requirements for ginseng production. These include studies of light interception as influenced by different shade materials. In North America, wood, woven black polypropylene and knitted polyethylene shade are used, whereas in China, dried grasses are bound together in layers with wire and polyvinylchloride is inserted between the layers. The influence of these various shade materials in terms of crop growth and root yield are presented. The major effect of temperature seems to be on root growth. During much of the growing season optimum temperatures for root growth are not reached. Growth analysis data for different age plants are being used to show the effects of different soil temperature regimes on distribution of dry matter between the shoot and root.

Introduction

Ginseng is usually grown for its storage root. At the same time as roots are growing stems, leaves and sometimes flowers and seed are being produced. Insufficient biomass invested in the vegetative organs gives a poor crop. A high investment in vegetative organs may give a high total biomass but a relatively low proportion may be used for the production of storage organs, especially if the maintenance requirements are high. Excessive vegetative growth can be compensated to only a limited extent by redistribution of dry matter from vegetative parts to storage organs.

The effect of environmental variables, particularly radiation and soil temperature, on the pattern of dry matter distribution to the various plant parts during phenological development could help in understanding the yield formation processes of ginseng. Phenological stages must be considered because the crop not only accumulates weight but passes through successive stages. These stages are characterized by the order and rate of appearance of vegetative and reproductive parts.

I hypothesize that the potential performance of a ginseng crop in any given environment can be predicted using only simple inputs such as temperature and radiation interception. However, the limits to potential performance must be given due importance at each stage in the life of the crop. As a first step towards yield prediction crop macroclimate and microclimate will be characterized and these related to crop phenology, performance and dry matter distribution.

Macroclimate

The major ginseng producing areas of the world are Korea, Japan, China, North America and the Soviet Union (Hong 1978). In order to compare macroclimatic data for some of these areas Table 1 was prepared. Selected data from two ginseng-producing areas in North America, one in China, and one in Korea have been summarized. Data for Seoul, Korea have been taken as representative of a major Korean ginseng producing area. The city of Changchun, China has been taken as representative of a major producing area, Jilin Province (Fig. 1). These are compared with 2 North American centers of production, the Lake Erie Counties of Ontario, Canada, and Wausau, Marathon County, Wisconsin, United States.

In general the differences between the 4 producing areas are not large except for rainfall which is much higher in Korea, and comes mainly in both China and Korea in growing season of June, July and August. This high rainfall and the high atmospheric humidity it induces could cause problems in disease control. Ohh (1981) reproted that root rot pathogens such as *Cylindrocarpon destructans*, *Fusarium solani*, and *Ramularia* sp., increased rapidly with increasing soil moisture. This root rot complex caused up to 60% loss of the crop.

Microclimate

The microclimate achieved in cultivation of ginseng

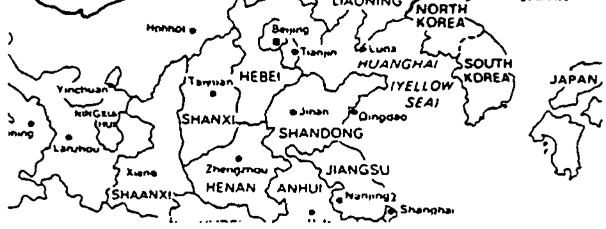

Fig. 1. Map of the major ginseng producing provinces in China. The region is bounded by North Korea and the Yellow Sea in the east, Inner Mongolia (Nei Monggol) in the west, the U.S.S.R. in the north, and east/west line through Shanghai (31° 12°N) and Xian (34° 15°N) in the south. (From Proctor et al 1988).

under artificial shade is a modification of the existing macroclimate. The primary objective in all the major producing areas of the world is to simulate hardwood forest conditions, the native habitat of ginseng. Although each country achieves microclimate modification in different ways each obtains the following:

(i) light attenuation by artificial shade of wooden lath, dried grasses (Fig. 2) or other means to 10 to 25% of full sunlight (Proctor 1980)

(ii) plant growth on raised soil beds covered with 50 to 100 mm of organic mulch such as straw (Cumie 1980) or hardwood leaves (Proctor et al. 1988) which ensures low-temperature protection of the roots (Proctor and Lee 1983), adequate soil moisture (Proctor and Bailey 1987) and optimum temperatures for root growth (Bailey et al 1988, Lee et al. 1986). Details of recent findings and current research about various aspects of these microclimate modifications will now be discussed.

Light attenuation. The radiation and energy balances of the shade environment for ginseng growing has been developed for a suspended polypropylene shade fabric by Stathers and Bailey (1986). A similar treatment has been developed by the traditional Korean shade environment by Kim (1964) and expanded upon and reviewed by Park (1980).

A number of Korean workers (Choi et al. 1982, Lee et al. 1980, Park 1980) have identified deficiencies in their growing environment. Because of the structure of the canopy light levels in the back of the beds are too low for optimal photosynthesis. Relative light intensity in a traditional five-row planting was 8-9% in the front rows, 2-3% in the middle rows, and 1-2% in the back-row (Lee et al. 1980). By improving the structural design and using different shade materials such as pine board, styrofoam board and polytex fabric light levels were increased, particularly in the rear rows of the beds and root yield was increased.

In China ginseng garden construction is based on traditional Oriental techniques (Hong 1978). For shade dried grasses [e.g. sorghum (*Sorghum vulgare* L.)] are bound together in layers with wire (Fig. 3) and a sheet of 0.1 mm thick green polyvinylchloride (PVC) is inserted between the layers held together by split bamboo poles attached to the garden super structure. The PVC sheet deflects rainfall into the shallow drainage channels around the growing beds. The Chinese shade allows about 25% of diffuse light to reach the crop and is more comparable to the woven black polypropylene shade used in North America than the wooden lath shade (Proctor 1980).

In North America polypropylene and wooden lath shades are still preferred. The effects of these shades on light and temperature were reviewed at the 3rd International Ginseng Symposium (Proctor 1980). Since then Stathers and Bailey (1986) have reported on the radiation balance for polypropylene shad fabric used in ginseng culture in the hot arid environment at Lytton, British Columbia, Canada. In general, light levels at plant height appeared adequate although the estimated surface area of 78% for this shade may be allowing too much light to reach the crop (Bailey, unpublished). A small shade experiment has been initiated in Ontario, Canada to evaluate newer shade fabrics in terms of root yield and seed production.

Temperature. Microclimate modification to attain a suitable environment in which to grow ginseng has a dramatic effect on the thermal regimes (Stathers and Bailey 1986). The soil temperature regime is effectively separated from the atmosphere even when air temperatures exceed 30°C (Fig. 4).

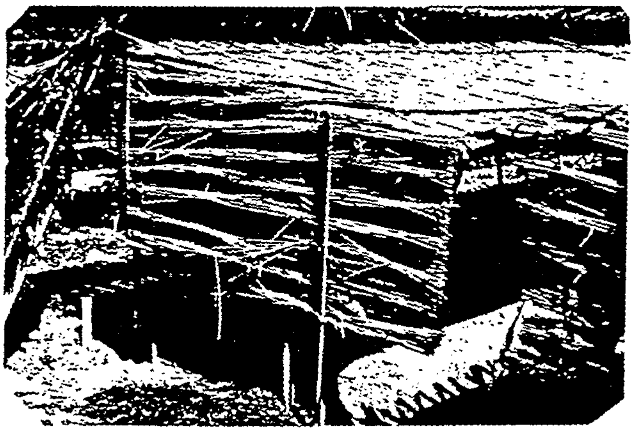

Fig. 2. Photograph of the end section of ginseng garden in China used for growing American ginseng. Plants are grown 50 to 100 mm apart in rows 0.20 to 0.25 m apart in the raised beds.

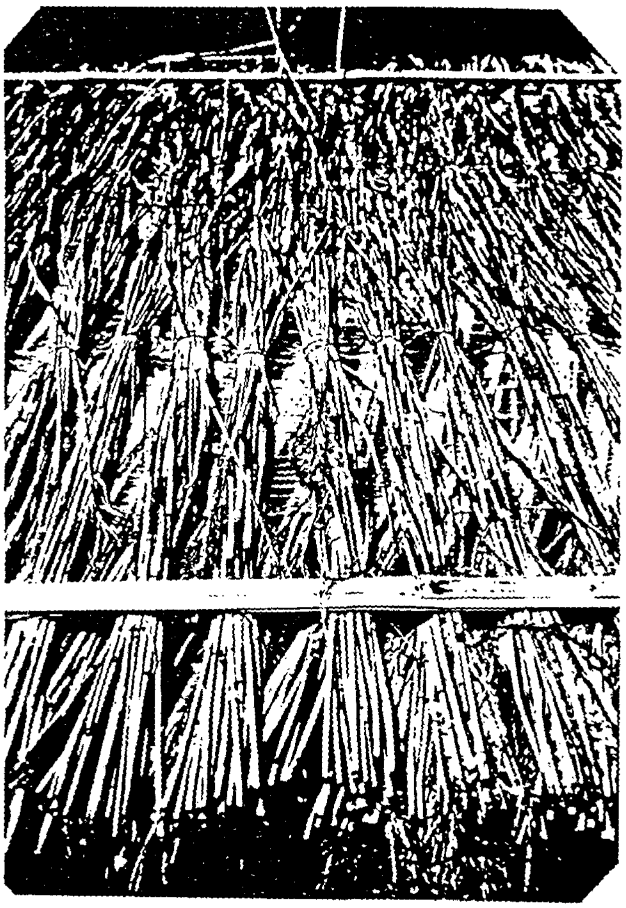

Fig. 3. Woven dry grass shade in a Chinese ginseng garden. The shade is in place and shows the retaining strips of bamboo at top and bottom and the sheet of rain shedding polyvinylchloride between the two layers of the woven dried grass.

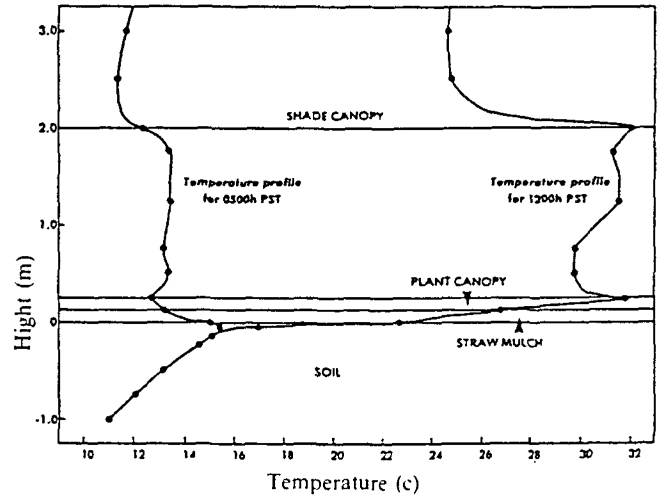

Fig. 4. Temperature profiles above and below a black polypropylene shade canopy during day and night on August 2, 1984 at Lytton, British Columbia, Canada. (From Stathers and Bailey 1986.)

Continuous records of soil temperatures in ginseng gardens around the world do not exist. Some data exist for soil temperature and plant growth during the growing season in a 2-year-old planting in British Columbia, Canada (Bailey et al. 1988). They showed that root growth was initiated at about 8°C. Maximum root growth was at 15-18°C under controlled conditions (Lee et al. 1986) but this was only met in the field late in the growing season and only for a short time. Similar conditions likely occur in all ginseng producing areas of the world. Therefore, there may be opportunities for increasing yield and reducing disease problems by manipulating the shade structure to obtain higher soil temperatures.

Air temperature optimum for ginseng growth is around 20°C (Lee et al. 1986). In all ginseng producing areas of the world this is likely to occur but the range is high and extremes likely. For instance, Stathers and Bailey (1986) reported extreme high temperatures of 35 to 40°C in British Columbia, Canada. The effects of these extremes on plant growth yield are unknow. Extreme low air temperatures of -30°C to 40°C probably do not damage roots since the soil mulch insulates the soil from the potentially damaging atmospheric environment.

Partitioning of dry matter

The partitioning of dry matter in ginseng is rarely reported. Usually only fresh and/or dry weight of the root at harvest is reported - for examples see Proctor et al (1988). Table 2. The partitioning of dry matter, however, is a dynamic process that changes continuously during growth. Ratios of shoot/root or seed/shoot and root at harvest quantify no more than the overall static end-product of distribution as influenced by the growth pattern from shoot emergence until harvest. In addition, partitioning is dynamic from year to year because phenological development varies from year to year and is influenced by factors such as climate, soil types and management practies. Therefore, data obtained at harvest cannot be used for predictive purposes under varying environmental conditions. For that purpose, it is necessary to examine the distribution to the various plant parts of the total dry matter increments between successive harvests during the annual growth cycle of all ages of plants.

Our first step in this work has been to harvest plants at various times during the growing season, separate the plants into their various parts, measure parameters such as stem length and leaf area and then dry the parts to obtain a measure of the partitioning of dry matter.

Figure 5 shows an example of the dry weight gain of a 2-year-old plant over the 1987 growing season. The changes in the pattern of dry weight can be divided into three periods. First, there is a time of no weight gain leading to loss in root weight (about day 130) as root respiration becomes active. This is followed by a second period of linear increase in root dry weight. Around day 230 root dry weight tends cease as the plant matures and enters into senescence.

This work is continuing. We are characterizing the

Table 1. Climate data for four ginseng producing areas: Lake Erie Counties of Ontario, Canada; Changchun, China; Wausau, Marathon County, Wisconsin, U.S.A.; and Seoul, Korea.'

Variable	Lake Erie counties Canada		Changchun China		Wausau Wisconsin U.S.A.		Seoul Korea	
Latitude	42°51 N		43°52 N		44°58 N		37°34 N	
Mean annual temperature (°C)	8.3		4.7		5.7		11.1	
Mean daily temperature and range (°C)	Temp	Range	Temp	Range	Temp	Range	Temp	Range
January	−4.4	7.8	−16.8	12.1	−11.3	10.3	−4.9	9.2
April	6.7	10	6.6	13.5	6.2	11.4	10.5	11.3
July	21.1	12.2	23.5	10.3	20.6	12.2	24.5	8.2
October	10.6	11.1	6.8	13.0	8.8	10.9	13.4	11.9
Extreme low temperature (°C)	−36.7		−36		−40		–	
Mean soil temperature in early February (°C)	−1.2		–		–		–	
Mean data of last frost in spring	May 12		May 5		May 12		April 5	
Mean data of first frost in fall	Oct. 10		Sept. 25		Sept. 30		Oct. 28	
Mean annual frost free period (days)	150		143		139		197	
Mean annual precipitation (mm)	864		632		813		1259	

'Modified from Proctor et al (1988) and Watts (1969).

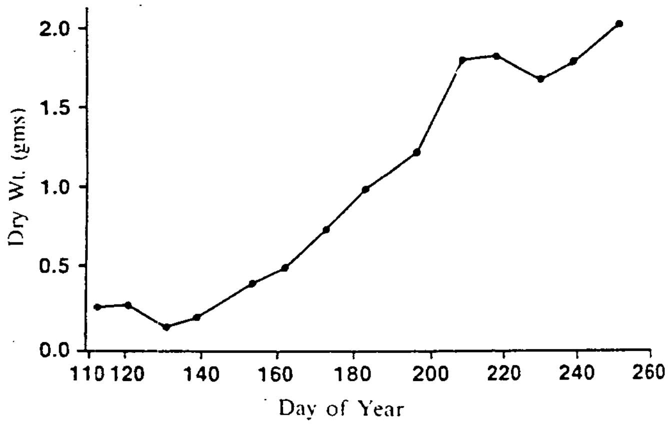

Fig. 5. Root dry weight increase of 2-year-old ginseng over the 1987 growing season. Each point is the average of 10 replicates.

microclimate, determining the partitioning of dry matter and integrating the results with the objective of predicting yield.

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Hoon Park: What factor do you think is the most limiting for slow growth of *Panax quinquefolium*? And what is the impact of *P. quinquefolium* cultivation in China to American ginseng business?

John T.A. Proctor: Ginseng is a shade-growing plant and adapted to growing in shade. It will not grow faster if placed in full sunlight. At the moment there is no impact. In the future, if production problems of America ginseng in China are overcome, China would satisfy her domestic needs for American ginseng and may even export it.

인삼 (*Panax* sp.) 재배를 위한 미세기상조건

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인삼은 한국, 일본, 소련, 북미에서 재배되고 있다. 이들 생산지역의 미세기상을 각각 조사해 보면, 인삼의 생육에 필요한 필수조건을 갖고 있으며 각 지역에 따라 미세기상은 다른 방법으로 조절되고 있다. 북미, 한국, 중국에서의 최근연구자료를 비교해 보면 인삼생산에 맞는 여러가지 미세기상 조건들을 구명 할 수 있을 것이며, 여러가지 해가림 재료에 따른 일광차단에 관한 연구도 미세기상 조건구명의 한가지 방법이 되고 있다. 북미에서는 나무와 polypropylene 해가림 재료가 사용되지만, 중국에서는 마른 풀을 엮은 이엉사이에 polyvinylchloride film을 넣어 해가림을 한다. 이러한 해가림 재료들이 인삼생육과 수량에 미치는 효과는 뿌리생육에 있는 것 같으며, 생육기간 중 대부분 뿌리의 생육 적온에 미치지 못하고 있다. 년근별 생육자료를 분석해 보면, 근권의 토양온도가 지상부와 뿌리의 건물 분배에 미치는 효과를 구명하는데 유용할 것이다.