Korean J. Ginseng Sci.
Vol. 12, No. 1, 53—62 (1988)

Seasonal Soil Temperature and Moisture Regimes in a Ginseng Garden

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(Received May 20, 1988)

Abstract

A field experiment was conducted in the arid interior of British Columbia, Canada to assess the seasonal soil temperature and moisture regimes in an American ginseng garden. As a consequence of the man-modified microclimate (elevated shade canopy and surface covering of mulch), the growing environment of the crop was fundamentally altered when compared to adjacent agricultural growing environments. In the ginseng garden, soil temperatures were found to remain low throughout the growing season whereas soil moisture remained high when compared with the outside garden environment. These results indicate that even in the hot, arid environment of the interior of British Columbia, the growing of ginseng is undertaken in sub-optimal conditions for the major part of the growing season. This poses challenges for the producers of the crop to modify the architecture of the gardens to enhance the soil regime without creating a deleterious aerial environment.

Keywords: American ginseng (*Panax quinquefolium* L.), soil temperature and moisture

Introduction

American ginseng (*Panax quinquefolium* L.) is a native, herbaceous perennial which is a component of the understorey of the deciduous forests of eastern North America. It prospers where diffuse solar irradiance and adequate soil moisture conditions occur during the summer growing season. The commercial cultivation of American ginseng necessitates that this growing environment be fully emulated. This is accomplished through the use of an elevated shade canopy and a surface covering of organic mulch. The former eliminates direct solar irradiance on the plants' leaves which will cause necrosis. The latter minimizes evaporation from the soil in the summer and prevents the injurious consequences of cold temperatures in winter. This man-modified growing environment has been extremely successful as American ginseng is now grown in many regions well outside its native range (Proctor and Bailey 1987).

Little is known about the nature of the growing environment of American ginseng (Proctor and Bailey 1987). Further, the response of the plant to the conditions found in

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these modified growing environments has not been documented. This is particularly the case in the arid interior of British Columbia where the commercial growing of ginseng has recently commenced. Previous work by Stathers and Bailey (1986) at a large commercial ginseng farm near Lytton, British Columbia has illustrated the unique short-term microclimate modification that results from the shade cloth and mulch. It was found that net irradiance was primarily dissipated as sensible heat and that latent heat was quite small. Further, the transfer of heat into the soil was also at a minimum. These short-term observations therefore have implications to the longer-term seasonal trend of environmental parameters. As a consequence of the high commercial value of this crop for its herbal and medicinal properties, this dearth of information has implications for both researchers and commercial producers.

The objective of this paper is to examine the seasonal course of soil temperature and moisture regimes in a large commercial ginseng garden. This will be undertaken in comparison with the regimes characteristic of adjacent, unmodified agricultural surfaces. The implications of the modified soil regime on some of the agronomic concerns facing the production and culture of the crop will be considered.

Materials and Methods

The research was conducted at a large commercial ginseng farm at Lytton, British Columbia, Canada in 1984. This farm is located in the arid interior of British Columbia, well outside the native environment of American ginseng. During the summer season, Lytton is one of the hottest and driest locations in Canada. The maximum temperatures for April, May, June, July, August and September 1984 were 25.4, 27.9, 32.6, 40.5, 34.6 and 28.1 °C and the monthly precipitation totals were 3.7, 19.0, 33.8, 3.6, 8.8 and 21.9 mm respectively for the same months.

During the growing season, measurements of environmental parameters were made in a second year ginseng garden (originally planted in September 1982). The garden was 135 m by 155 m and was covered with black polypropylene shade canopy (Chicopee Lumite Fabric) that was suspended approximately 2 m above the ground. The garden soil has a silty clay texture and a bulk density ranging from 1.0 to 1.3 Mg m^{-3}. The plants were grown in raised beds which were covered with 50 to 100 mm of straw mulch. The beds were 1.35 m wide and ran the length of the garden in a north-south direction. Plants were grown at a high density of approximately 180 per square meter of garden bed.

The outside garden environment was characterized as native pasture and it had a surface cover of legume and grass species. The soil was identical to that of the garden in terms of texture and bulk density.

At fourteen intervals from April through September, soil temperature and moisture measurements were made in both the garden and native pasture. Soil temperature measurements were made at two locations within each. Measurements were made manually using thermocouples mounted on a wooden dowel permanently inserted into the soil. Depths of measurement were 0, 0.05, 0.15, 0.25, 0.50, 0.75 and 1.00 m in the garden and down to a depth of 0.75 in the native pasture. Measurements were made in the early afternoon, near the time of peak near-surface soil temperature. Previous results (Stathers and Bailey 1986) for this garden have illustrated the slowly changing thermal regime of the soil. This arises as a consequence of the use of the shade cloth and surface covering of mulch which restricts heat transfer into the soil. Hence, the measurements made well document the seasonal trend of the soil thermal regime.

Soil moisture measurements were collected from five randomly selected sample sites. Samples were extracted using a corer at increments of 50 mm, from the surface to a depth of 250 mm. These samples were fresh weighed, oven dried at 105 °C for 24 hours and then dry weighed. This, together with previous determinations of bulk density, allowed the calculation of volumetric soil moisture.

Continuous air temperature and precipitation measurements were made on-site using a recording thermohydrograph and raingauge. Other supplemental meteorological measurements were available from the Atmospheric Environment Service station located in Lytton, British Columbia.

Results and Discussion

Seasonal trend of air temperature and precipitation

The maximum and minimum air temperature regime for the 1984 growing season is presented in Figure 1. A seasonal trend, that is characteristic of the interior of British Columbia, is evident, In the spring, minimum temperatures are limiting. During the summer maximum temperatures are high, at times reaching 40 °C. In early autumn, the return of low minimum temperatures is again evident.

Figure 2 shows the course of daily precipitation during the growing season of 1984. The frequency of precipitation is low throughout the growing season, particularly in July and August. During the six month period, only one daily precipitation value exceeded 10 mm. During the period April 1 to September 30, the total precipitation was 90.8 mm.

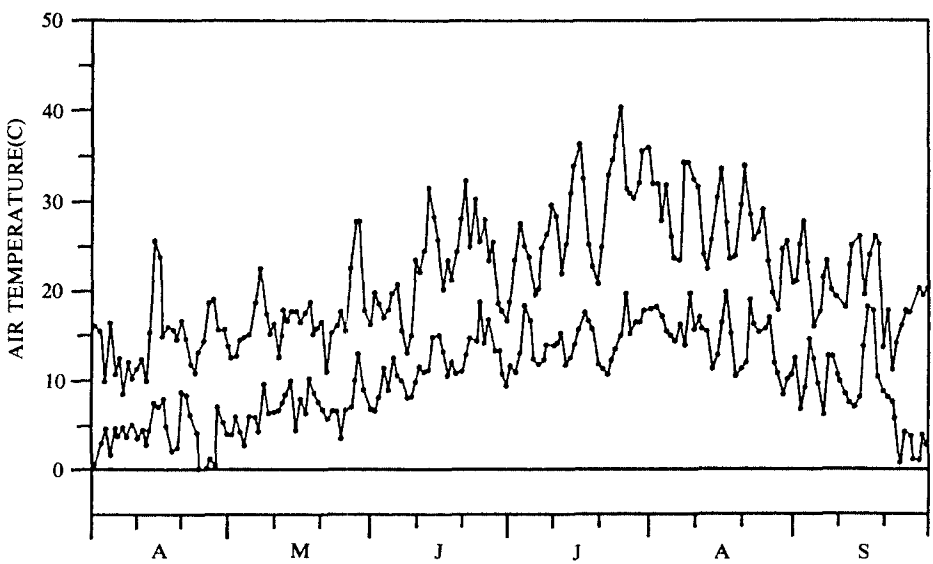

Fig. 1. Daily maximum and minimum air temperature for Lytton, British Columbia for April through September 1984.

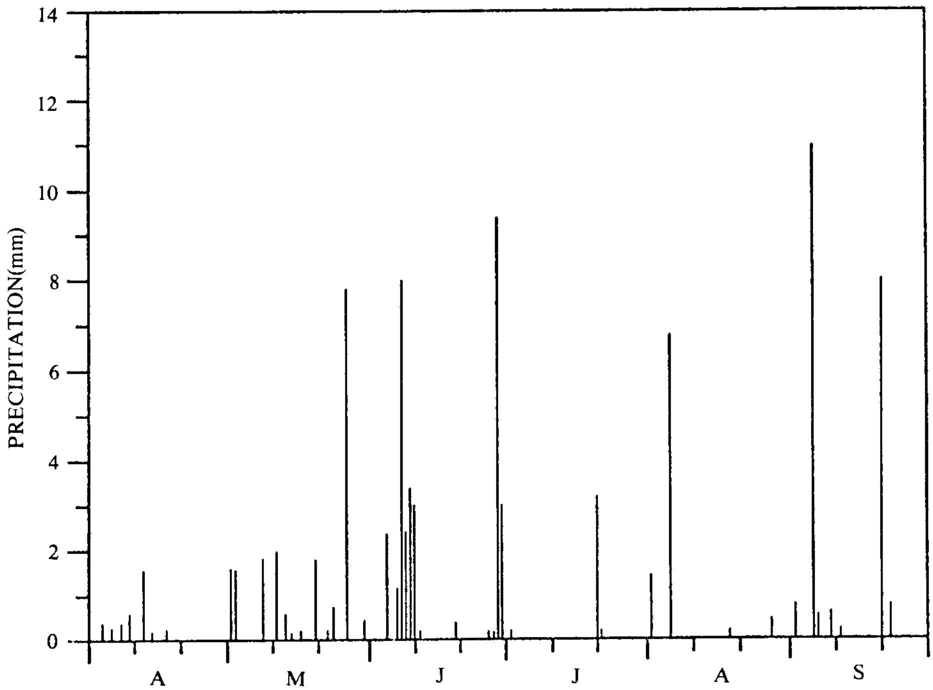

Fig. 2. Daily precipitation for Lytton, British Columbia for April through September 1984.

Seasonal trend of soil temperature

The soil temperature at four depths (0.05, 0.15, 0.25 and 0.50 m) is presented for both the second year ginseng garden and the native pasture in Figure 3. The impact of the shade cloth and mulch on the thermal regime of the soil in the ginseng garden is quite evident. For all depths, the soil temperature in the ginseng garden is appreciably cooler. As is expected, the amplitude of the seasonal temperature trend is suppressed with depth. In Figure 4, sample soil temperature profiles are presented for periods near the end of the months of April, May, June, July and August. It is clear that the impact on the soil thermal regime is dramatic and is characteristic over the full depth of the agronomically significant part of the soil profile.

The rationale for these results has been presented by Stathers and Bailey (1986). The elevated shade cloth minimizes the amount of solar and longwave irradiance that reach the garden surface. Of the irradiance both above the shade canopy and at the garden surface, most is dissipated as sensible heat. In fact, there is only minimal latent and soil heat transfer. Little energy is available for soil heating and as a consequence of the plant canopy and the straw mulch, there is little heat transfer into the soil. Measurements of soil temperature throughout the day confirm this as the diurnal change in the soil temperature profile is minimal below the 0.05 m depth. Consequently, the course of soil temperature in the ginseng garden shows little in the way of a diurnal trend. Rather, soil heating is low and the seasonal profile, even in the surface layers, exhibits characteristics similar to deep soil layers in which no surface modification has occurred.

The impact of soil temperature on the growth and yield of American ginseng has not been well documented in the field. Fortunately, some research has been conducted

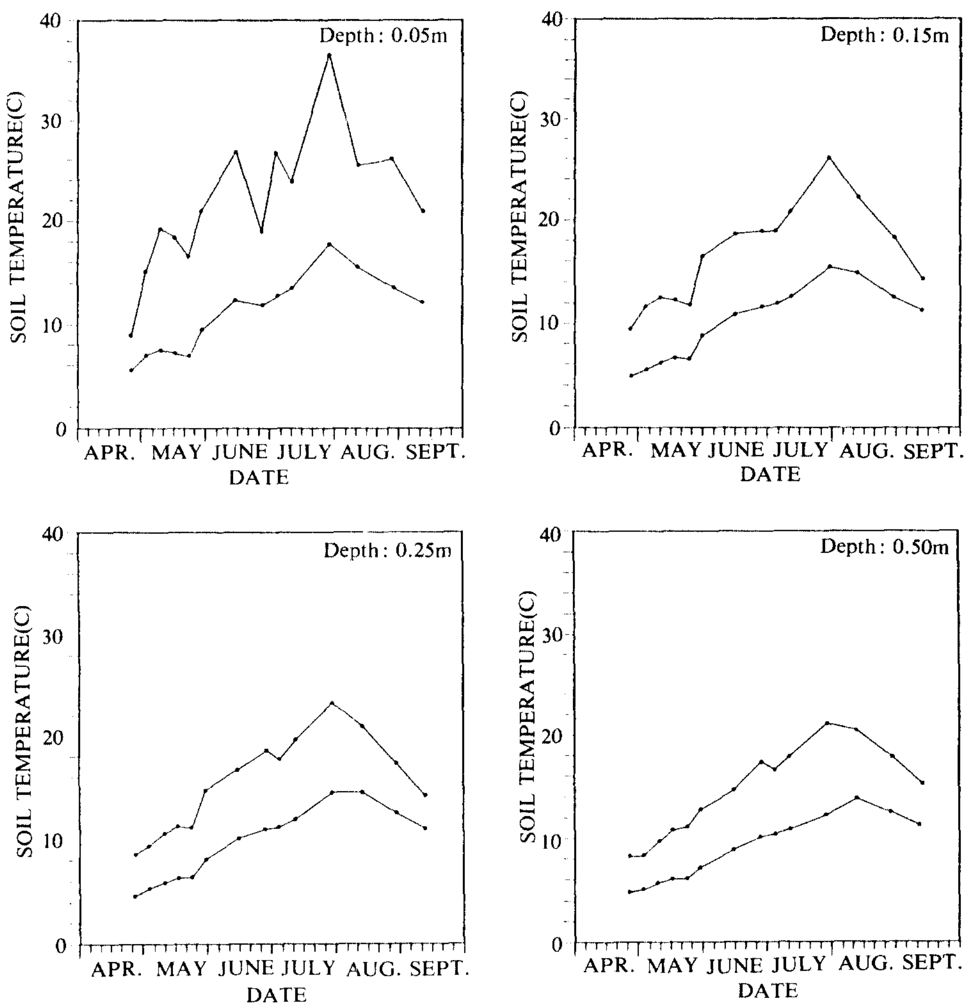

Fig. 3. Soil temperature for four depths for the second year ginseng garden and the native pasture for April through September 1984. In each graph, the upper line is for the native pasture and the lower line for the second year ginseng garden.

employing greenhouse and growth chamber studies. The work of Lee *et al.* (1986) illustrates that for maximum American ginseng dry matter production, soil temperatures between 15 and 18 °C would be desirable. It is evident from the data displayed in Figures 3 and 4 that this desired range is outside of the regime found over most of the growing season. In fact, this optimum temperature range is reached only during late July and early August in the surface to 0.15 m depth interval, which characterizes the rooting zone. It is also apparent that if this is the case at Lytton, British Columbia with its hot and arid climate, then in many other regions using the same cultivation techniques, the soil thermal regimes must also be sub-optimal for large portions of the growing season.

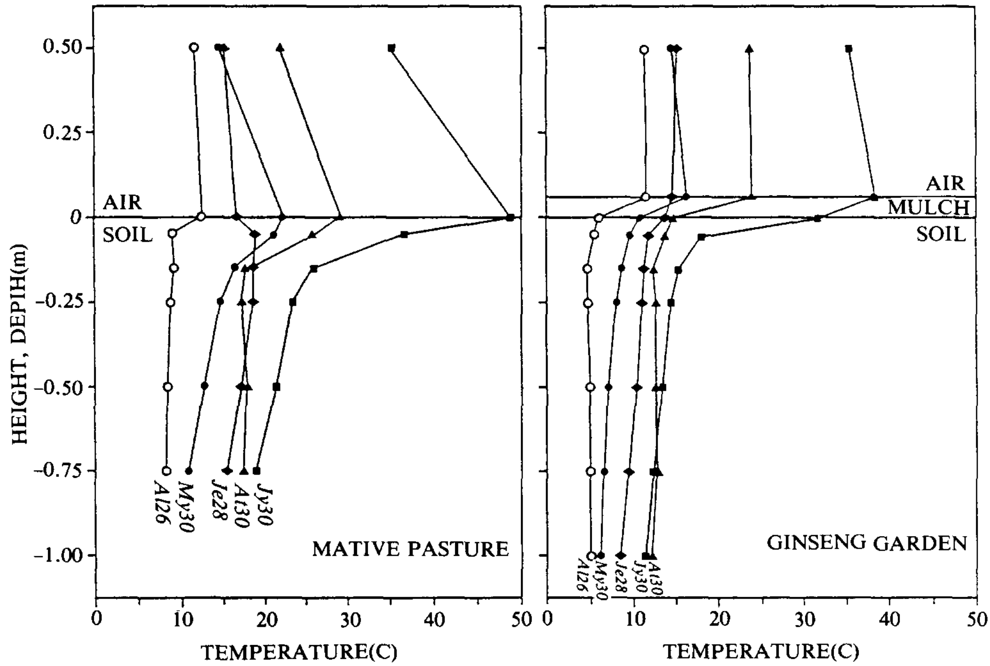

Fig. 4. Soil temperature profiles for the second year ginseng garden and the native pasture for periods near the end of April (Al), May(My), June(Je), July(Jy) and August(At).

Seasonal trend of soil moisture

The seasonal trend in soil moisture for the depth interval 0-0.25 m for the second year ginseng garden and the native pasture is presented in Figure 5. It is clear from this figure that the two regimes are quite distinct.

For this soil, the -1.5 MPa matric potential value, as determine by pressure plate analysis, is 13.9% volumetric soil moisture and the -0.01 MPa matric potential value is 28.9% volumetric soil moisture. Hence it is evident for this soil with native pasture, that once June begins, the soil moisture regime is extremely limiting for both plant survival and growth. For the second year ginseng garden, soil moisture remains near saturation levels until well into August. After this, there is a decline in soil moisture below 0.25 mm^3 H_2O/mm^3 soil. It is important to emphasize that no irrigation water was applied to the ginseng garden during the growing season.

Figures 6 and 7 detail the seasonal trends in soil moisture for five depth intervals for the ginseng garden and the native pasture. The data for the native pasture illustrate the ranges usually found in such dryland conditions. In particular, the surface layers of the soil remain dry throughout the major portion of the growing season. The impact of this regime is evident in the nature of the pasture vegetation. Without irrigation, the vegetation is sparse and little growth occurs after June. For the ginseng garden, it is noted that the differences between the soil layers is minimal .This confirms field observations that the soil in the garden appears to be uniformly wet with depth. Throughout the major part of the growing season, the soil moisture is near field capacity for the entire soil pro-

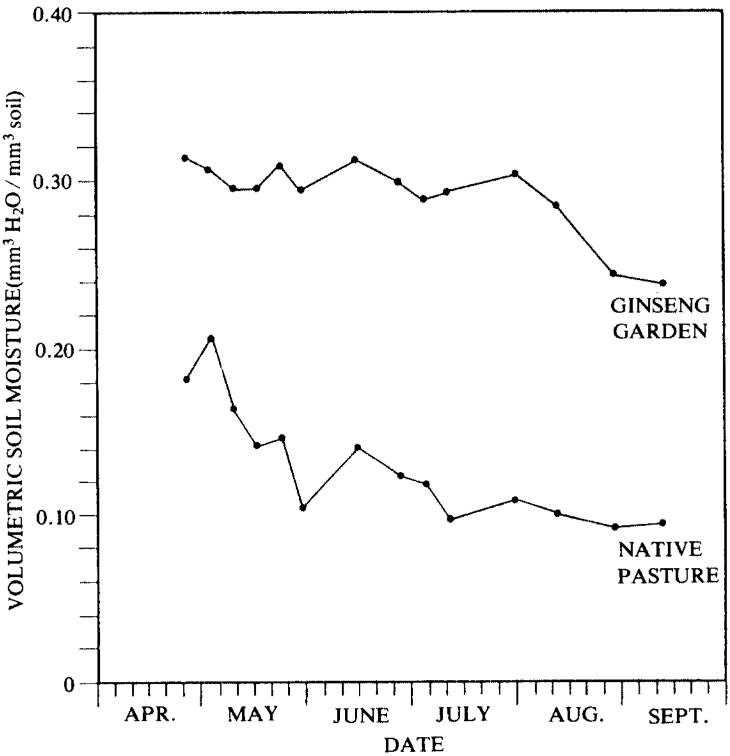

Fig. 5. Volumetric soil moisture for the second year ginseng garden and the native pasture for April through September 1984. Depth of measurement is 0-0.25 m.

file. It is only in August that sufficient loss of soil moisture has occurred from evaporation and transpiration that the soil moisture begins to decline.

Short-term measurements of latent heat transfer made by Stathers and Bailey (1986) have illustrated that surface evaporation and plant transpiration are low. This occurs even when soil moisture levels were high. It is apparent from the data in Figures 5 and 7 that this is the case for a large portion of the growing season. The low rate of soil evaporation, even when soil moisture is high, is related to the high diffusive resistance to vapour transfer imposed by the straw mulch. Plant transpiration is low, again even when soil moisture levels are high. This implies that stomatal conductances are very low even though leaf area index for the second year garden was between 1.5 and 2.0. These low conductances may result from the high leaf temperatures, which many times exceed 40 °C during the months of July and August, and low vapour pressures in the air. Each of these environmental conditions can induce stomatal closure. Also the extreme temperature differences between the leaf and root temperature may play a contributing role. It is clear that more detailed physiological measurements of stomatal resistance and internal plant water status are needed in these environments to fully document the physiological control over water efflux.

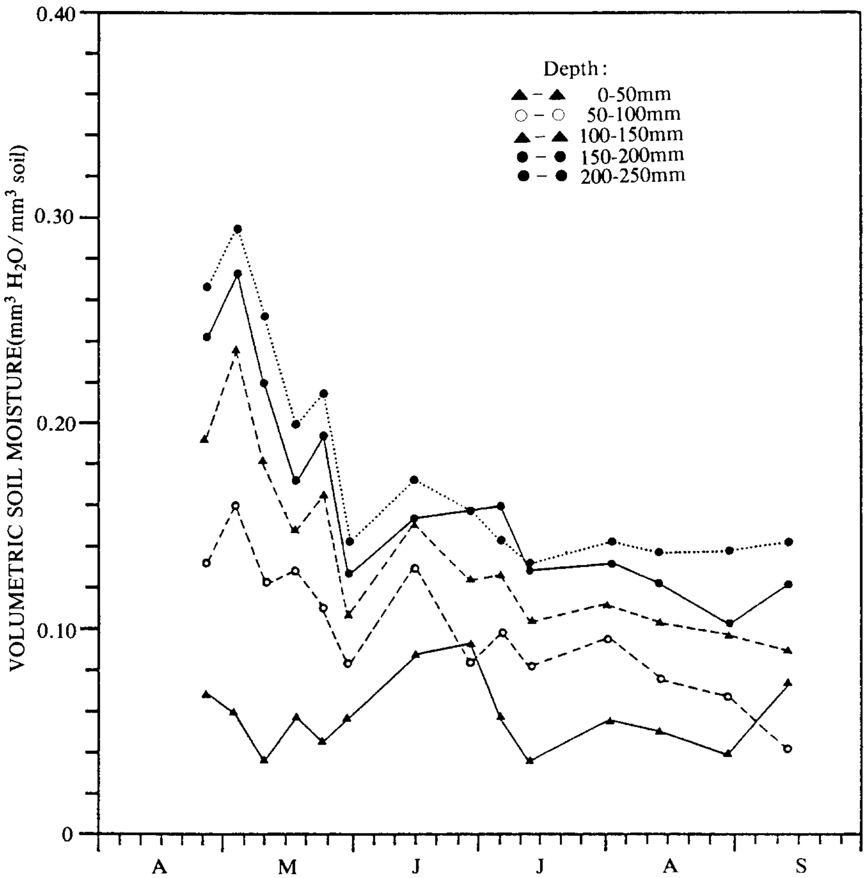

Fig. 6. Volumetric soil moisture for the native pasture for five depth intervals for April to September 1984.

Conclusions

The use of an elevated shade canopy and surface covering of organic mulch has a great impact on the microclimate of the growing environment of American ginseng. This is particularly evident when one considers the seasonal trend of soil temperature and moisture. As a consequence of the effective decoupling of the soil regime from the atmosphere, the soil temperature remains cool during the entire growing season. In fact, soil temperatures near the surface in the ginseng garden are directly comparable to those at a depth of approximately one meter in adjacent, unmodified agricultural surfaces. Unfortunately such soil temperatures are sub-optimal for the growth of ginseng and are characteristic of a major part of the growing season. When soil moisture is considered, the high levels are maintained throughout the season. This indicates the effective role of the shade canopy and mulch on the conservation of soil moisture. Consequently, American ginseng can be commercially grown in more arid regions than originally considered.

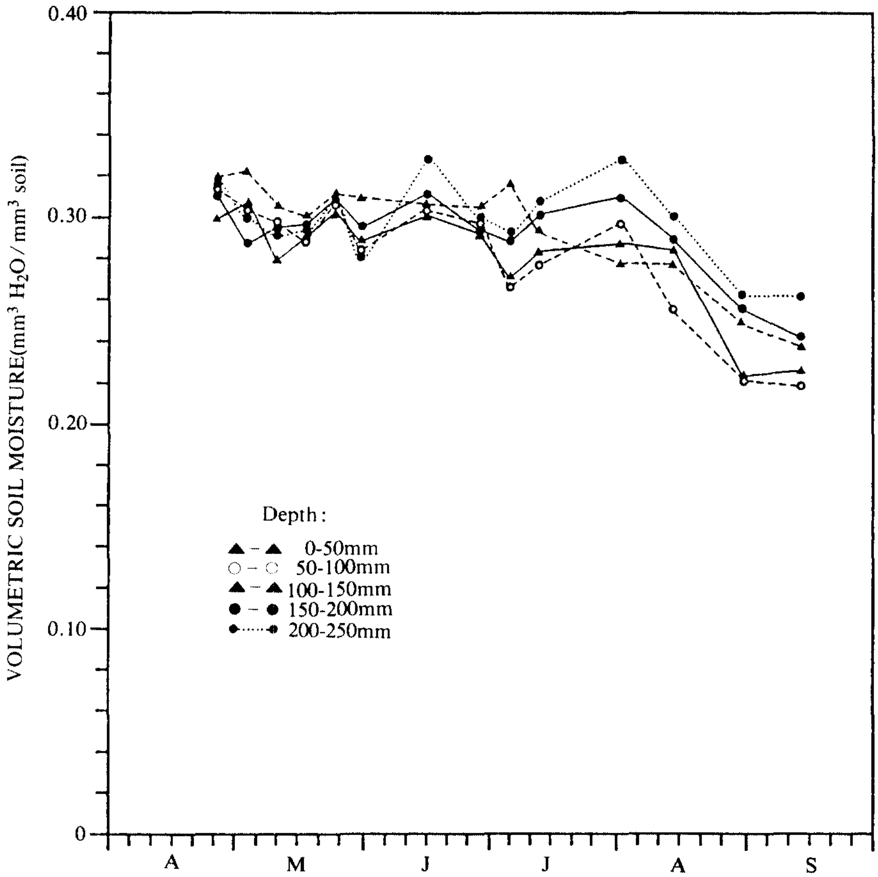

Fig. 7. Volumetric soil moisture for the second year ginseng garden for five depth intervals for April to September 1984.

This research also partially explains the high incidences of fungal diseases found in ginseng crops throughout the major producing regions in the world. It is clear that the microclimate modification used, while creating a successful growing environment for the crop, also has a wide host of environmental niches for the growth and survival of fungal pathogens. This is particularly evident when one considers the fact that there are steep thermal and moisture gradients present within the organic mulch layer. Given that the commercial growing cycle of American ginseng is now four complete growing seasons, it is easy to appreciate the high probability of disease occurrence.

These research results illustrate that American ginseng can be commercially grown over a wide geographical range. In fact, it is suggested that it is well suited to dryland environments. It is also clear that increased research is needed in other years of ginseng gardens and in other regions to more fully understand the linkages between the use of artificial shade and mulch and the seasonal characteristics of the growing environment. Further, work must also be directed to the study of the plant in such environments to both understand its behaviour as well as to maximize root dry matter production. These results challenge both researchers and producers to re-evaluate the architecture of ginseng gardens to preserve the positive features of the modified environment while overcoming the features that pertain to cool growing season soil temperatures and over-abundant soil moisture. These limit plant growth as well as create a host environment for fungal pathogens. All efforts to refine the nature of the growing environment must be undertaken with due consideration of the necessity of not creating a deleterious aerial environment.

Acknowledgement

We are grateful to Chai-Na-Ta Ginseng Products Ltd., Lytton, British Columbia, Canada and particularly their President, Mr. J.M.M. Latta, for providing access to their farm for research purposes. This research was funded in part by an Operating Grant (A2614) from the Natural Sciences and Engineering Research Council of Canada.

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