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Seasonal Growth and Root Respiration of North American Ginseng

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Abstract : American ginseng plants (*Panax quinquefolium* L.) of various ages were harvested every two weeks during each of three growing seasons and dry matter yield of components and root respiration determined. Shoot dry weight was about 0.5 g, 2.5 g and 4 g for 2, 3 and 4-year-old plants, respectively and fruit dry weight was as much as 50% of this in 3- and 4-year-old plants. Root dry weight decrease by 30~50% as shoots emerged and at the end of the season was about 2 g, 3.5 g and 5 g in 2, 3, 4 and 5-year-old plants, respectively. Shoot and root dry weight were linearly related with an approximate 1:2 ratio. Root respiration rate at 20℃ in the dark was about 5 μg CO_2 g^{-1} DW(dry weight) min^{-1} in the early season, then doubled within 50 days as shoots emerged, and thereafter declined over the season to 2~5 μg CO_2 g^{-1} DW min^{-1}. The Q_{10} for dark respiration over the interval from 10 to 20℃ was 1.58. Root respiration rate and shoot growth rate were positively linearly related in all ages of plants.

Key words: Dry weight, partitioning.

Introduction

North American ginseng (*Panax quinquefolium* L.) is one of Canada's aboriginal plants which has become a highly valuable cash crop.[12] It was discovered growing in Canada in the 1700s at which time trade in it was established between Canada and the Orient which continues today.[4,5] Ginseng was originally collected from Canadian hardwood forests and has been cultivated for the last 100 years for its highly valued root. The root contains ginsenosides (saponins or glycosides) which are used as tonics, adaptogens and aphrodisiacs. The chemistry and pharmacology of *Panax* has been reviewed recently.[2]

Ginseng is a perennial shade growing root crop with a low photosynthetic rate slow growth rate.[11,13] Plant growth depends on the balance between photosynthetic carbon gain and respiratory carbon loss.[3] In many plant species carbon loss through respiration accounts for 30~60% of the photosynthates produced with a significant portion of these losses occurring in the roots.[8,10] The development of management strategies for ginseng culture that optimize the various environmental factors (eg., radiation and temperature) will lead to maximizing plant growth and yield potential. Although ginseng is cultivated extensively in North America,[12] little is known about its physiology and carbon economy. Due to low leaf photosynthetic rate and large root weight as a portion of total plant weight, root respiration may be very important in controlling root growth of American ginseng plants. Little is known about the seasonal growth and root respiration of American ginseng.

The objectives of this research were to study the growth rate and dry matter partitioning of shade-grown American ginseng and to quantitate root respiration and its relationship to growth.

Materials and Methods

At regular intervals during three growing seasons, (1988~1990) plants of 2-, 3-, 4- and 5-year-old ginseng growing commercially under typical Ontario conditions[13] were dug, placed in plastic bags and taken to a constant temperature room held at 20±1℃. Plants were separated into their various components, weighed and dried to constant weight at 80℃. At each sampling date, ten plants were selected randomly and dug. Sample size was considered representative.[6] Prior to drying, root samples, usually of 10 roots, were taken for respiration measurements in the dark using methods previously described.[15] In addition to the majority of measurements made at 20℃ the rates of respiration of roots were measured over the range 5 to 20℃.

In the field root-zone soil temperatures were measured at 10 cm using LI-COR model 1000-15 soil temperatures probes and recorded hourly on

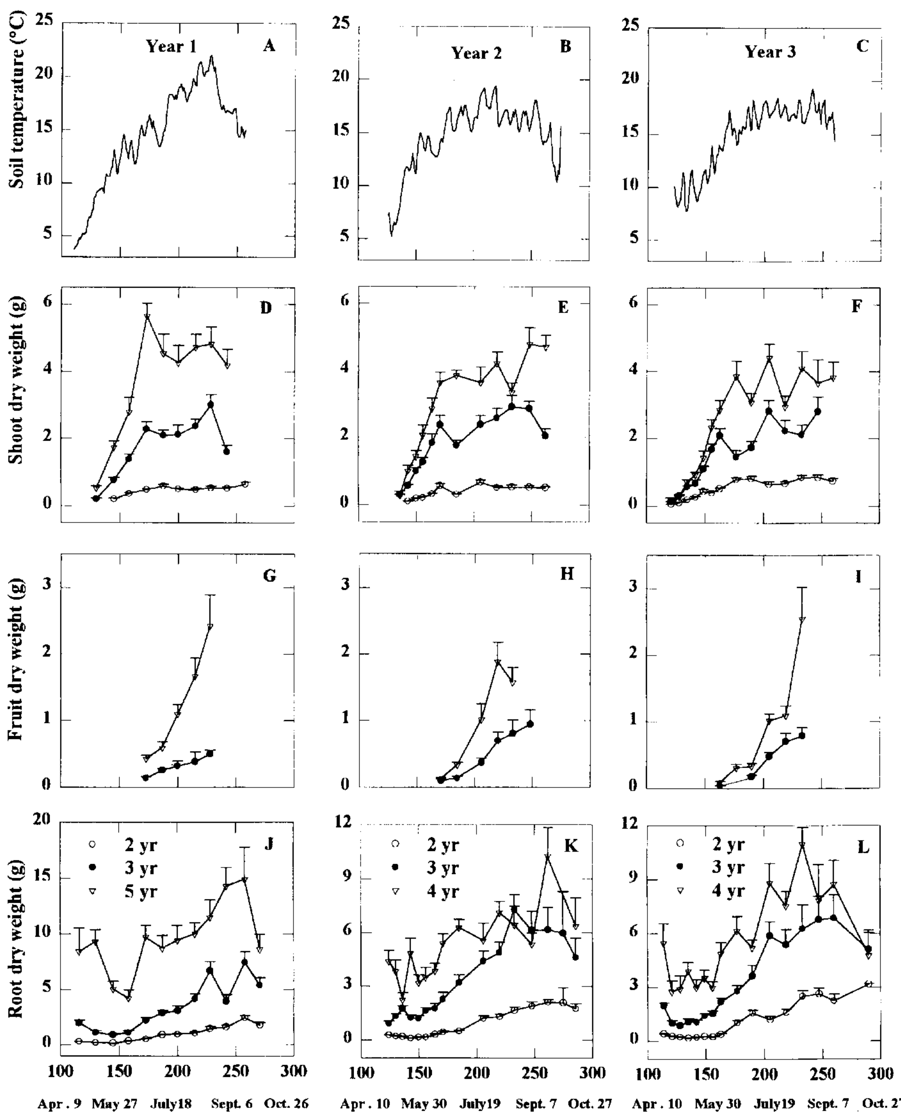

Fig. 1. Seasonal field soil temperature at 10 cm (A, B and C) and shoot (D, E and F), fruit (G, H and I) and root (J, K and L) dry weight (mean and standard error) of different age plants (2, 3, 4 or 5 years as indicated by symbols) for each of the 3 years.

LI-1000 dataloggers (LI-COR Inc., Lincoln, NE).

Results and Discussion

1. Soil temperature

The average daily soil temperature at 10 cm below the surface during the growing season increased from approximately 5℃ in mid-April to 18~22℃ in July and August and then decreased to around 15℃ (Fig. 1A, B, C). These data complement the those for the seed stratification period which showed stratifying box temperatures decreased from 15℃ in September to 1℃ in December, remained constant for about 100 days and then increased in the next 50 days to 10℃.[14] In our earlier controlled environment work on air and root-zone temperature effects on ginseng growth and root yield we predicted maximum dry matter production at a soil temperature of 15~18℃.[9] Data in Fig. 1A, B and C show that in each of the 3 years soil temperature during the June, July and August growing period were mostly in the 15~18℃ range.

Soil temperature during shoot growth initiation, as estimated by shoot dry weight (Fig. 1D, E and F) was at about 7~8℃. This is similar to our previous work where we estimated shoot emergence at 10℃ at 5 cm under grass sod[9] and 8℃ in a two-year-old ginseng garden.[1]

2. Shoot dry weight

Shoot growth started in late April or early May with the older plants developing new shoots first (Fig. 1D, E, F). Rapid shoot growth (ie, leaf and stem dry weight gain) occurred from late April or early May to June and there was very little shoot growth afterwards. Shoot dry weight of fully developed leaf canopy was about 0.5 g 2.5 g and 4 g for 2-year, 3-year and 4-year old plants old plants, respectively.

3. Fruit dry weight

Flowers in the inflorescence set fruit in late May and these started to develop in June in 3- and 5-year-old plants (Fig. 1G, H, I). Fruit dry weight of these plants was as much as 50% of

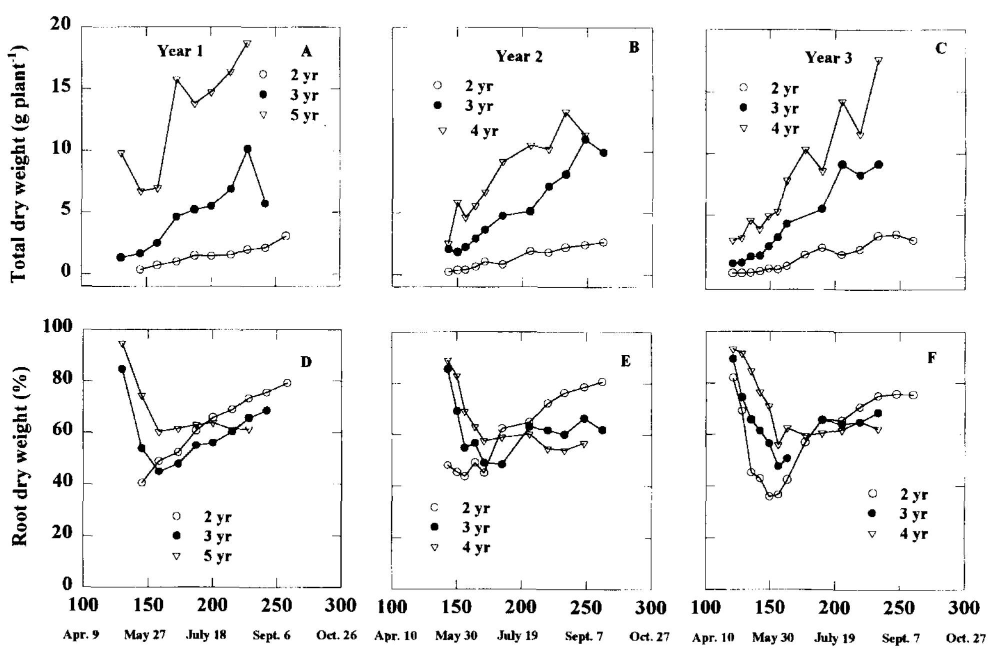

Fig. 2. Seasonal changes in total plant dry weight (A, B and C) and percent root dry weight of total plent dry weith (D, E and F) of different age plants (2, 3, 4 or 5 years as indicated by symbols) for each of 3 years.

vegetative shoot dry weight in late season. Partitioning of so much dry weight to fruit is undesirable if growers wish to maximize root yield rather than grow fruit and seeds. We have demonstrated that inflorescence removal in early July will increase root yield by 25%.[16]

4. Root dry weight

Root dry weight generally decreased by 30~50% at the beginning of the growing season and recovered the losses by mid-June (Fig. 1J, K, L). The actual root growth occurred from mid-June until early September. In some instances root dry weight at the final sampling date was lower than at the previous date particularly in older roots. We connont explain this as the onset of shoot senescence would suggest partitioning of materials to the root system and therefore increases in root weight. The net gain in root dry weight from late April or early May to October was about 2 g for 2-year-old, 3.5 g for 3-year-old, and 5 g for 5-year-old roots (Fig. 1J, K, L).

5. Total plant dry weight

The amount of total plant dry matter gain during the growing season increased with plant age. The total dry matter gain for 2-, 3- and 4-year-old plants was 2.5 g, 4.5 to 8 g and 9 to 15 g, respectively (Fig. 2A, B, C).

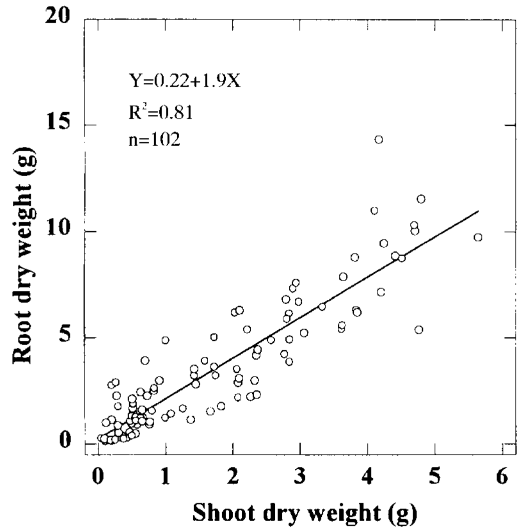

Fig. 3. Relationship between root and shoot dry weight of ginseng plants. Data for different plant ages over the 3-years period were pooled.

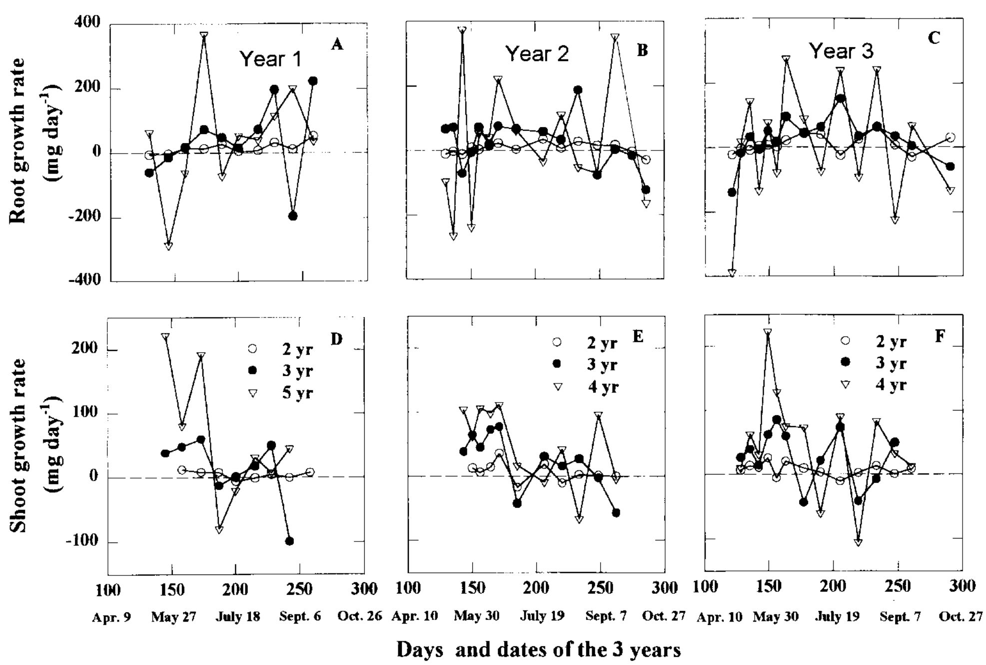

Fig. 4. Seasonal fluctuations in root (A, B and C) and shoot (D, E and F) growth rates of different age plants (2, 3, 4 or 5 years as indicated by symbols) for each of 3 years.

6. Dry matter partitioning to roots

Dry matter partitioning to roots as a percentage of the total plant dry weight decreased rapidly from early May to early June due to new shoot growth (Fig. 2D, E, F).

The percentage root dry weight was lower in 2-year roots than in older roots during this period. Afterwards, root/total dry weight ratio in 2-year-old plants continued to increase to 75 to 80% at the end of the growing season. The root/total dry weight ratio increased to 62 to 68%. However, root dry matter in 4- and 5-year-old plants remained at 57 to 61% from early June to October.

7. Relationship between root and shoot dry weight

The growth data from the 3-year study indicate that there was a linear relationship between vegetative shoot dry weight and root dry weight with an approximate 1:2 ratio (Fig. 3). In our greenhouse studies with ginseng seedlings we found shoot to root ratio of approximately 1:2[9] suggesting, with the data, above, that this ratio may be relatively constant, at the end growing season, for all ages of ginseng.

8. Root and shoot growth rate

Root growth rate (mg day^{-1}) fluctuated more with the increase in plant age (Fig. 4A, B, C). In general, root growth rates were negative (ie, decrease in dry weight) at the beginning of the growing season. The range of shoot growth rate during a growing season was less than that of root growth rate. Maximum shoot growth rate occurred during early growing season with higher rates in older plants (Fig. 4D, E, F). The growth rates of roots and vegetative shoots were positively correlated (Fig. 5).

9. Root respiration

Respiration rate of intact roots measured at

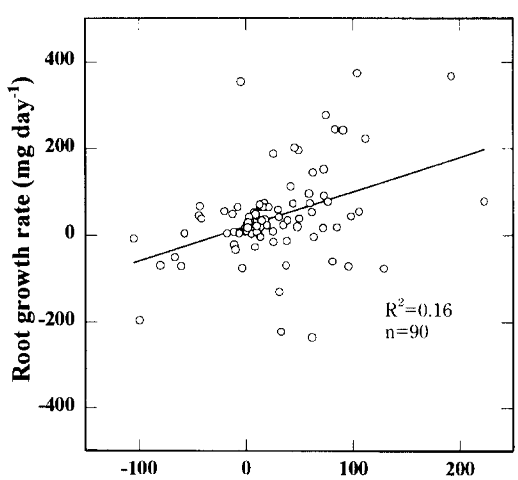

Fig. 5. Relationship between root and shoot growth rate. Data from different plant ages were pooled over the 3 year period.

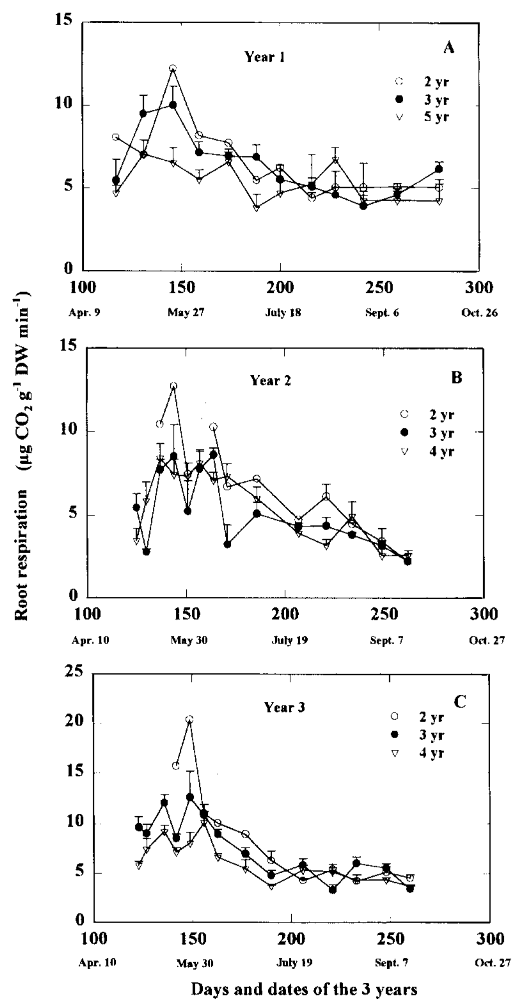

Fig. 6. Seasonal changes in root respiration (mean and standard error) of different age plants (2, 3, 4 and 5 years as indicated by symbols) in each of 3 years. DW=dry weight.

20°C ranged from 2 to 20 μg CO_2 g^{-1} DW min^{-1}, depending on the age of the plants and the time of sampling (Fgi. 6). These rates for early season, about 5 μg CO_2 g^{-1} DW min^{-1} (equal to 100 mg CO_2 kg^{-1}) FW hr^{-1}) are relatively high compared to many fruits and vegetables.[7] Rates of 10 μg CO_2 g^{-1} DW min^{-1} were common during shoot emergence and approached those for asparagus. Possibly these high rates at shoot emergence are typical for perennial root systems as they become more metabolically active in the spring. Root respiration rates fluctuated the most during the first 2 months of plant growth with rates increasing with shoot emergence and then declining. Root repiration rates were relatively stable from July to October in Years 1 and 3, whereas in Year 2 there was a more gradual decline in root respiration over the same period. Root respiration rates of younger roots were generally higher than older roots in early season and the differences in respiration rates between the ages diminished as the season progressed.

Root respiration rate increased linearly with increase in assay temperature with a Q_{10} of 1.58 from 10°C to 20°C (Fig. 7). Data over the 3 year study indicate that root respiration rate decreased linearly with increase in both root dry weight (Fig. 8A) and shoot dry weight (Fig. 8B). Further analysis showed no correlation between root respiration rate and root growth rate in all ages of plants studied (data not shown). However, there was a positive linear relationship between root respiration rate and vegetative shoot

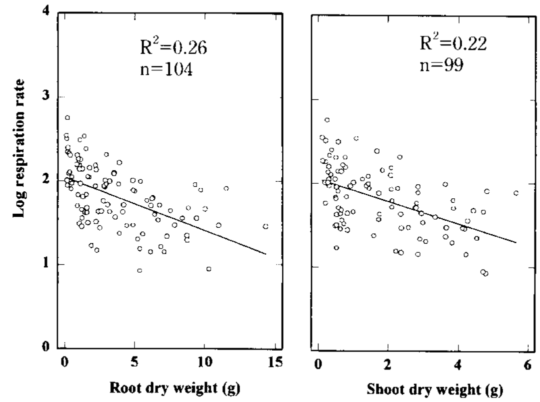

Fig. 8. Linear relationship between log (natural) respiration rate and root and shoot dry weight. Data represents plants of different ages over the 3 years of the study.

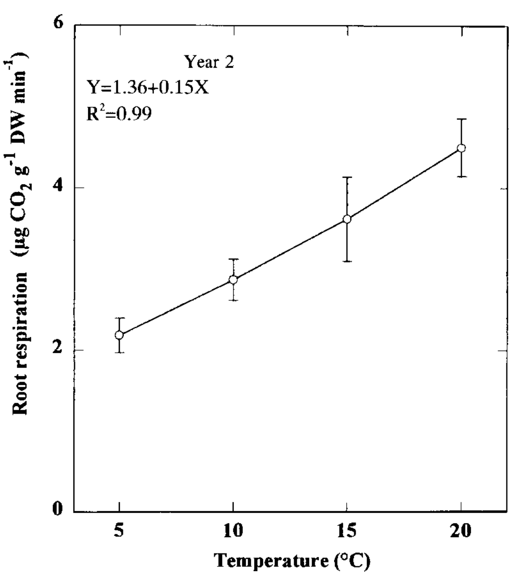

Fig. 7. Root respiration (mean±standard error) in response to temperature change. Data for 3- and 4-year old plants were pooled. DW=dry weight.

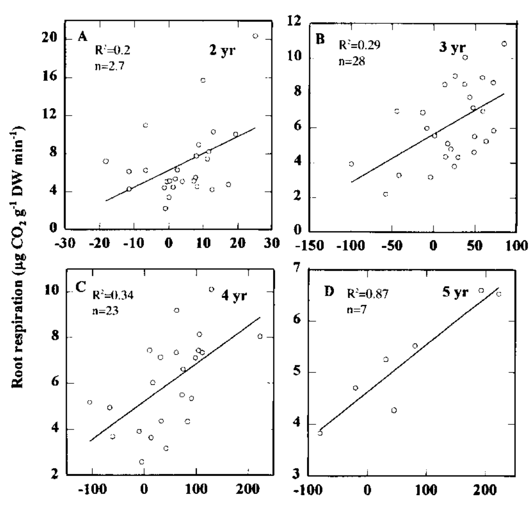

Fig. 9. Relationship between root respiration and shoot growth rate of 2, 3, 4 and 5-year old plants. DW=dry weight.

growth rate of all ages of plants (Fig. 9).

Acknowledgements

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