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Dormancy and Growth of American Ginseng as Influenced by Temperature

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Abstract. **American ginseng (*Panax quinquefolium* L.) roots have a dormancy period which can be satisfied by exposure to low temperatures of 0° to 10°C for about 100 days. Three-year-old roots of ginseng were weighed, given variable periods (≥ 50 days) of low temperature (5°C), planted in vermiculite in pots, and grown in light or dark at 5°, 10°, 15°, or 20°. After 50 to 100 days of storage at 5°, stem growth occurred at all temperatures except 20°. At this temperature, a minimum of 75 days at 5° was required to satisfy dormancy. Stem growth rate was relatively constant at 5° and 10° but increased with storage time when grown at 15° or 20°; leaf growth rate was affected similarly, except that no leaf growth occurred at 5°. If optimum cold storage and growth requirements were not met, the plants appeared abnormal and had reduced root dry weights. After 100 days of storage, the greatest growth rate was observed at 15° and 10°. Plant growth rate was the least at 5° and 20°.**

The perennial root crop, American ginseng, has a dormancy period which can be satisfied by exposure to low temperature. The nature of this obligatory cold period is not known. Stoltz (5) has indicated that 90 days of chilling at 5°C induced bud break of yearling roots. Because of the high value of this crop, some of its future propagation and production likely will be by tissue culture (1). Before these techniques can be used, more will need to be known about the dormancy period, particularly the optimum temperature and its duration. Since dormancy is relatively long, attaining optimum growth as soon as possible is desirable.

The objectives of this work were to determine the optimum temperature for dormancy of ginseng roots and to determine growth in the light and dark at various temperatures after receiving various periods of low temperature treatment.

Materials and Methods

In a preliminary study, 3-year-old roots of American ginseng were placed in cold storage at −1.1°, 4.4°, 7.2°, or 10.0° ± 0.5°C and, at intervals, moved to a greenhouse maintained at 22° ± 2° during the day and 16° ± 2° at night. Storage at 4.4° for 100 days was needed to give maximum plant growth. Thus, in subsequent studies, a low-temperature treatment of 5° was used.

Three-year-old roots of American ginseng were dug from a commercial planting on 3 Nov. 1982 (Day 1). They were placed in plastic bags in which high humidity was maintained with moistened vermiculite. The bags were placed in storage at 5° ± 2° and 50% ± 5% RH. On each of 5 different dates, 22 Dec. 1982 (Day 50), 6 Jan. 1983 (Day 65), 16 Jan. (Day 75), 24 Jan. (Day 85), and 8 Feb (Day 100), 128 roots were removed from cold storage, weighed, and planted in medium grade vermiculite in 21 cm diameter pots with 4 roots per pot. Half of the pots (16) were placed in continuous light of 50 μmol s^{-1} m^{-2} at the top of the pots, with 4 pots each at temperatures of 5°, 10°, 15°, and 20°C. The other 16 pots were placed in continuous darkness, with 4 pots at each of the 4 temperatures.

At weekly intervals, the following measurements of plant height and length and width of the central leaflet were made in each plant. At the termination of the experiment (Day 172), the

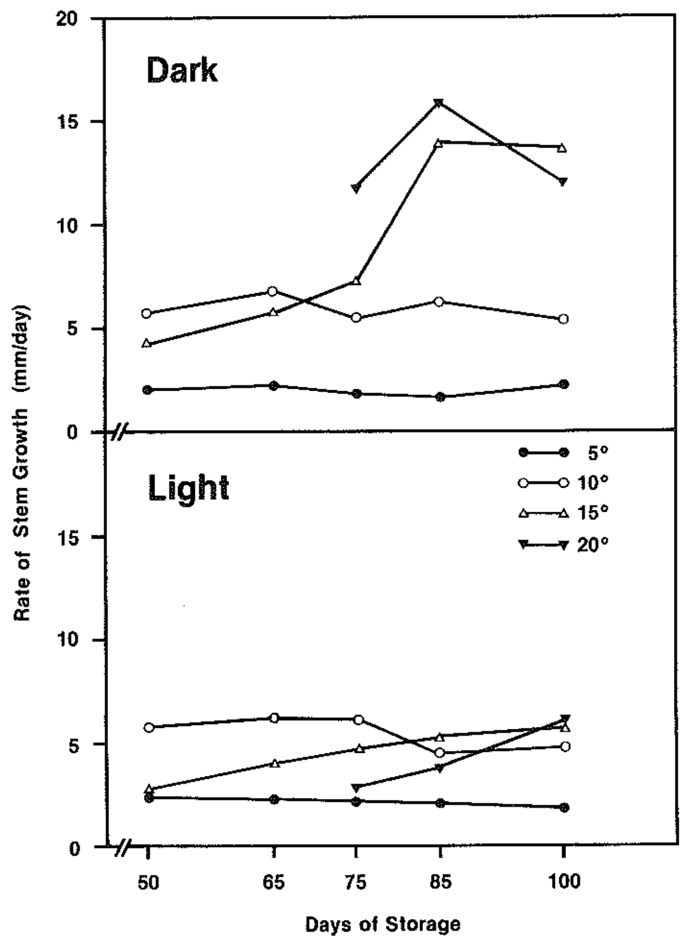

Fig. 1. The rate of stem growth of ginseng plants under continuous light or dark as influenced by length of storage period of roots (days at 5°C) and subsequent growing temperature. Each point represents a mean of 16 plants. $LSD_{0.05}$ = 6.92 mm/day.

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plants were separated into roots, stem, and leaves, weighed, dried to constant weight at 80°, and reweighed. Leaf area was calculated as described previously (2).

Linear regression was used to analyze the data for stem growth and leaf expansion. The resultant regression coefficients gave the rate of stem growth (Fig. 1). The plant growth rate (Fig. 4) was derived from the harvest data. These growth rate data were analyzed by a split-split plot analysis of variance.

Results and Discussion

Stem growth. Once ginseng roots were taken from storage and placed under continuous light at various temperatures, stem growth was initiated. The stem growth curve was sigmoidal, and the shape was unaffected by growing temperature or length of storage. However, the rate of stem growth, as determined by the slope of the linear portion of the curve, differed among treatments (Fig. 1). After 50 to 100 days of storage, stem growth in the light at 5° and 10° was relatively constant, but when grown at 15°, the rate of stem growth tended to increase as length of storage time increased. A minimum of 75 days of storage was required for stem growth if plants were grown at 20°: stem growth rate tended to increase with storage time at this temperature. In the dark, the stem growth rate was similar to growth in the light at 5° and 10°. However, at 15° and 20°, the rate of stem growth was greater in the dark than when grown under continuous light. Previously Park et al. (4) showed that the optimum temperature for ginseng shoot growth in the dark was a constant temperature of 15° or a split temperature of 15°/20° for 15 and 9 hr, respectively.

The optimum rate of stem growth occurred at 15° or 20°C in the dark (Fig. 1). At 5° or 10°, stem growth rate appeared constant or showed a declining trend in both the light and the dark, indicating that these temperatures are suboptimal for maximum stem growth rate. The increase of stem growth rate linearly with storage time when grown at 15°C indicated that, although dormancy was satisfied at 50 days, the capacity for growth was lower than when stored for longer periods.

Leaf growth. Leaf growth was measured throughout the experiment, and growth rates were obtained in the same manner as previously described for stem growth rate. Of those plants grown at 10°C under continuous light, the leaf growth rate was about 50 mm^2 per day and was unaffected by length of storage time. However, at 15° or 20°, there was a trend towards an increase in leaf growth rate with an increase in storage time. No leaf growth occurred when plants were grown at 5° in the light or at any temperature in the dark. Therefore, leaf growth had a different temperature requirement than stem growth.

Stem dry weight. Stem dry weight tended to decrease as storage time increased when grown at 5°C (Fig. 2). However, when grown at 15°, the trend was for increasing stem dry weight with an increase in storage time. At 10° or 20° there was no significant effect of storage time on stem dry weight, although plants grown at 20° had a lower stem dry weight than those grown at the other temperatures (Fig. 2). When the plants were grown in the dark, there were no significant differences in stem dry weight between those grown at 5°, 10° or 15° (0.16 ± 0.03 g). However, those plants grown at 20° had a significantly reduced stem dry weight (0.09 ± 0.03 g). At 15°, the linear increase in stem dry weight with an increase in length of storage indicated that the increased capacity for growth after a prolonged period of storage (Fig. 1) lead to a greater final dry weight (all plants were harvested on Day 172 irregardless of the storage time). At low temperatures, particularly 5°, the capacity for growth did not increase with length of storage. Thus, after 100 days, the final stem dry weight was reduced (less time to grow until harvest).

Root dry weight. The length of storage at 5°C had little effect on the final root dry weight. However, the temperature at which the plants were grown after storage did have an effect (Fig. 3). Those plants grown at 15° had the greatest root dry weight, whereas those grown at 5° had the lowest. When the growing temperature was 5° there was little difference in root dry weight between the light or the dark treatments. However, those plants

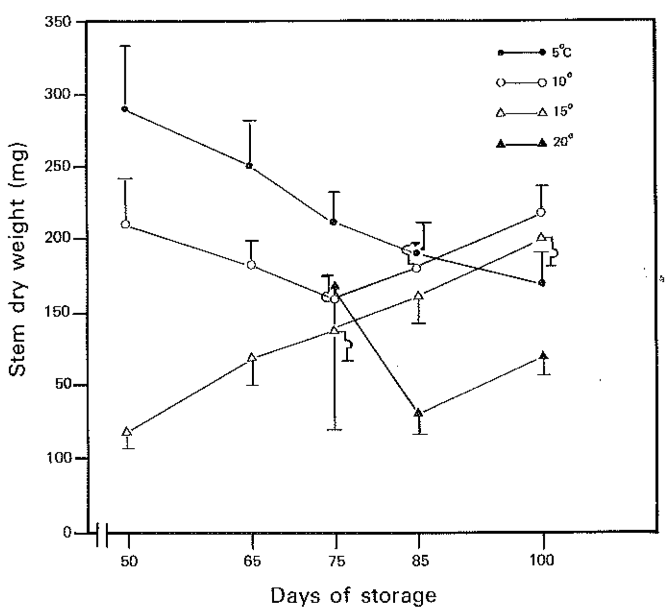

Fig. 2. The influence of length of storage of roots (days at 5°C) and subsequent growing temperature on the final stem dry weight of 3-year-old ginseng plants grown under continuous light. Each point represents the mean and its SE.

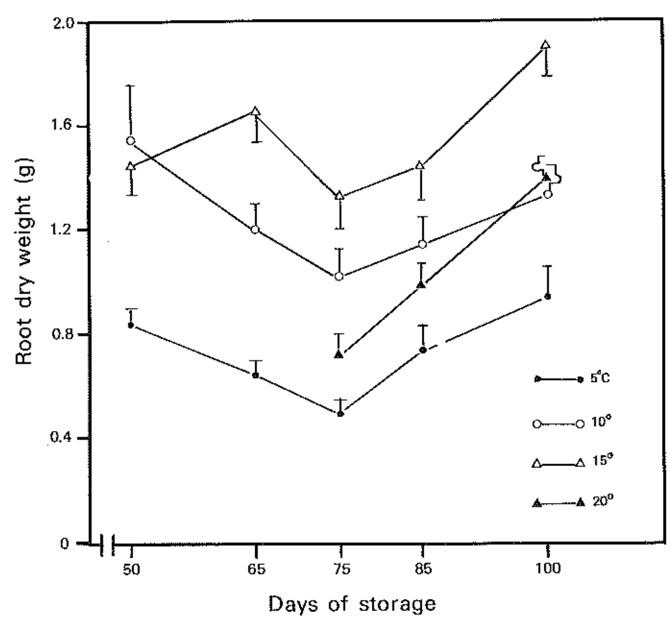

Fig. 3. The influence of length of storage of roots (days at 5°C) and subsequent growing temperature on the final root dry weight of 3-year-old ginseng plants grown under continuous light. Each point represents the mean and its SE.

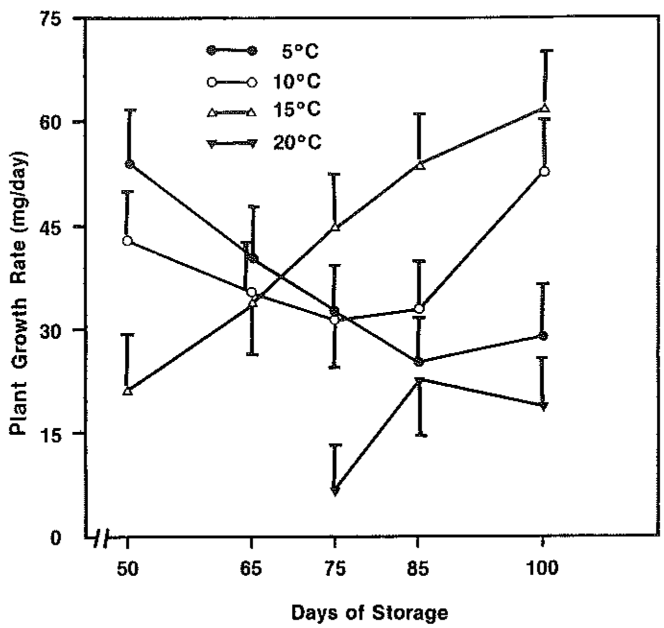

Fig. 4. The influence of length of storage of roots (days at 5°C) and subsequent growing temperature on the plant growth rate [(total plant final fresh weight − initial root fresh weight)/time available for growth] of 3-year-old ginseng plants grown under continuous light. Each point represents the mean and its SE.

grown at 10°, 15°, or 20° had a lower root dry weight if grown in the dark than if grown in the light (data not shown). Plants grown at 5° had low root dry weights because there were no leaves formed at this temperature, and, therefore, there was no photosynthesis. Root reserves were used for the stem growth that occurred. When plants were stored for less than 75 days, there was no significant difference in the amount of final root dry weight at 10° or 15°. However, at 5° or 10°, a declining trend was apparent. Perhaps, at these temperatures, respiration accounted for the decline. As dormancy became satisfied with an increase in storage time, respiration increased, thus leading to a reduced final root dry weight. After Day 75, there was a trend, evident at all temperatures, for an increase in final root dry weight with an increase in length of storage. At 10°, 15°, or 20° this increase would seem to indicate an increased capacity for assimilate partitioning to the root with a longer storage period. At 5°, however, as there was no photosynthesis but respiration, the increase may be due solely to the short length of time plants had to grow until harvest (Day 172).

Plant growth rate. After storage for 50 days, the plant growth rate (PGR) was greatest when plants were grown at 5° or 10°C (Fig. 4). However, the PGR at these temperatures decreased with an increase in length of storage time to 75 days. When stored for 85 to 100 days and grown at 10°, the PGR increased, whereas at 5° it appeared to reach a constant rate. Plant growth rate increased linearly with storage time when plants were grown at 15°. A similar trend was apparent for 20°; however, the growth rate seemed to reach a constant after 85 days of storage. Thus, after 100 days, the greatest growth rate was observed at 15° and 10° and the lowest rate at 5° and 20°.

This study of growth patterns of the parts of the ginseng plant at the different temperatures indicates maximum growth at 15°C and 100 days storage. At this temperature, stem growth rate, leaf growth rate, stem dry weight, and PGR increased linearly with time after 50 days storage at 5°. This linearity also held for final root dry weight, but 75 days storage at 5° were needed before this trend was initiated.

Little consideration has been given to the mediation of these temperature effects. It seems likely that endogenous phytohormones are involved, since we have been able to shorten the root dormancy period by exogenous application of gibberellic acid to the rhizome (unpublished data). A similar effect has been shown for oriental ginseng, *Panax ginseng* (3).

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