ROOT CHILLING DORMANCY REQUIREMENTS FOR AMERICAN GINSENG (*PANAX QUINQUEFOLIUM* L)

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ABSTRACT

Dormant one-year-old ginseng roots were subjected to a range of stratification temperatures and time to define effective limits to these parameters and to quantify their effect on terminating dormancy. Effective storage temperatures tested ranged from 0°C to 9°C. A low percentage of roots produced tops with as few as 30 days in stratification; however, 75 to 90 days were required for 100 percent emergence. Days to emergence, after planting, decreased with increased days in storage thru the maximum storage time of 120 days.

The number of days of dormancy was relatively constant, near 126.5 days, over the range of effective temperatures and acceptable storage times. The minimum period of dormancy was associated with 75 days in storage at 3°C. Root growth rate, after emergence, was greatest following 105 days of stratification. The frequency distribution of emergence with days in stratification suggests the potential of selecting for strains of ginseng with low chilling needs for satisfying dormancy requirements.

INTRODUCTION

The geographic range of native American ginseng generally is limited to the temperate climate between 34° and 45° North Latitude in eastern North America. Plants in the wild or in outdoor cultivation within this region are exposed to an annual cycle of temperatures that includes 4 to 8 months of frost-free weather during which the top emerges, develops and senesces. During this period a new bud is formed at the apex of the underground rhizome and then is subjected to 4 to 8 months of cool or cold soil temperatures during the dormant period.

Failure of American ginseng to exist in more southerly climes outside of its native range may be due 1) to the inability of the specie to tolerate the higher temperatures during the growing season or 2) to failure of fulfilling dormancy requirements of the root-bud.

In a preliminary experiment the necessity for chilling of roots to break dormancy was determined. Roots stratified at 3°C produced new top growth when placed in a growing environment; those stored at 14.4°C failed to produce tops (1). Moreover, the time to emergence from those roots stored at 3°C after removal from storage was inversely proportional to the length of time in storage.

A replicated experiment was conducted in 1981-82 to explore the range of temperatures that would satisfy chilling requirements and to quantify the influence of chilling time on satisfying those requirements.

MATERIALS AND METHODS

The experiment utilized one-year-old roots grown in outdoor beds under 75 percent wood lath shade at the Mountain Horticultural Crops Research Station, Fletcher, North Carolina. These were dug on October 21, 1981, after complete senescence of the tops. Soil temperature was approximately 13°C. Roots were stratified (stored) between layers of damp spaghnum moss in controlled temperatures of -15, 0, 3, 6, 9, 12, and 15°C. At 15 day intervals over a period of 120 days from the beginning of stratification, ten representative roots were removed from each stratification temperature, weighed and planted in individual 0.6 liter pots containing a soil-base medium. Containers were placed under shade in a glasshouse with temperature extremes of approximately 15 and 27°C. A control sample of roots was planted in containers and placed in the glasshouse with no stratification. Date of visible emergence thru the soil surface of each container was recorded. After senescence, roots were lifted on October 11, 1982, washed free of soil and their fresh weight recorded. The data were subjected to standard statistical analyses(3).

RESULTS AND DISCUSSION

Stratification Temperature. Roots stratified at -15°C became flaccid after thawing when removed from the storage chamber for planting. None of these initiated growth and were found to have decomposed after planting. All other roots appeared normal; however, there was no emergence from roots stratified at 12 or 15°C, regardless of storage time (Table 1).

Thus, under the conditions of this experiment, temperatures which permitted termination of root-bud dormancy were 0, 3, 6, and 9°C. These results suggest that the acceptable temperature range for satisfying root-bud dormancy requirements is between 9 and 12°C for the upper limit (a nominal upper limit of 10° is suggested) and -15 and 0°C for the lower limit. Proctor (2) reported damage to roots and rhizomes following exposure to temperatures below -10°C. The minimum acceptable temperature, therefore, appears to be between -10 and 0°C.

Stratification Time. No roots stored for fewer than 30 days (including control roots), regardless of storage temperature, produced top growth (Table 1). Percent emergence from the 30-day period of stratification was low, ranging from zero percent at 0°C to 30 percent at 6°C. The percent emergence within the acceptable temperatures increased with additional time in storage. Ninety percent of roots stored for 45 days at 3°C produced tops. Storage temperatures of 3 and 6°C resulted in 100 percent emergence with 60 days of stratification. With 90 days or longer stratification time, emergence was 100 percent for each of the acceptable temperatures tested.

Days-to-Emergence. The number of days

Table 1. Percent of tops emerging following stratification of ginseng roots.

Stratification temperature (°C)	Days in Stratification							
	15	30	45	60	75	90	105	120
-15[A]	--	--	--	--	--	--	---	---
0	0	0	20	90	100	100	100	100
3	0	10	90	100	100	100	100	100
6	0	30	50	100	100	100	100	100
9	0	20	60	90	90	100	100	100
12	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0

All roots from -15°C stratification decomposed.

from termination of stratification and planting to emergence was taken as one *criterion* of evaluating chilling requirements. These values were calculated for each root that produced top growth and were analyzed statistically. (The 30-day data were deleted from the analysis of variance because of analytical difficulties presented by the absence of data for the 0°C/30-day treatment combination.) Both storage temperature (Ts) and days-in-storage (Ds) significantly affected the days-to-emergence (De); however, the storage time had greater effect than temperature (Table 2). De, when averaged across temperature, decreased continuously from 81 days with 45 days storage to 16 days with 120 days of stratification. In contrast, the time to emergence was relatively constant for temperatures of 0, 3, and 6°C, ranging from 41 to 44 days, and increased to 50 days for 9°C storage (Table 2).

The data were subjected to regression analyses to determine the degree and nature of dependence of De on storage temperature and time. A quadratic regression equation gave a good fit (R=-0.9402) between days to emergence and storage time (Fig. 1). The correlation was much poorer (R=0.1403) between days to emergence and storage temperature and the degree of dependence very low (Fig. 2).

Among the four acceptable temperatures tested, 3 and 6°C gave the shortest delay (41 and 42 days, respectively) from planting to emergence (Table 2). Based on the criterion of minimum days to emergence, these two temperatures would be judged optimum for stratifying roots.

The storage period that resulted in the quickest emergence was 120 days, the longest period tested (Table 2), and the slope of the regression line was still negative (Fig. 1). However, differential calculus was used to determine the zero slope point on the curve. This point was at Ds=129.5 and De=15.2. This suggests that the minimum time to emergence would have been 15.2 days with 129.5 days in storage.

This is speculative, however, since these values were not tested.

Although additional time in storage might have revealed an actual minimum De, it can be argued that in reality minimum days to emergence is not an appropriate criterion for judging optimum days in storage. All buds were able to break dormancy with only 90 days storage; with some temperatures, even fewer days produced 100 percent emergence (Table 1). One might ask whether or not the additional chilling was beneficial or simply delayed emergence from buds that had satisfied their dormancy requirements.

Day of Dormancy. In this study, ginseng root-buds were defined as dormant from the beginning of the stratification period until emergence.

Table 2. Number of days from planting to emergence from one-year-old ginseng roots stratified at four temperatures for six periods of time.

Temperature (°C)	Days in Stratification						
	45	60	75	90	105	120	mean[B]
0	80	63	40	32	28	19	44
3	68	64	42	31	23	16	41
6	79	65	41	31	23	14	42
9	98	71	53	40	20	15	50
mean[A]	81	66	44	34	24	16	

[A] LSD (.01) for comparing days in stratification means = 4.

[B] LSD (.01) for comparing temperature means = 3.

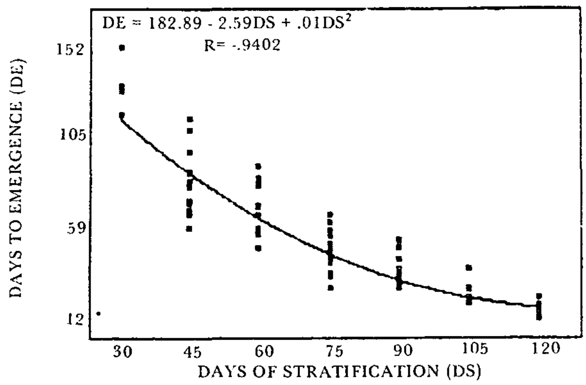

Fig. 1. Days to emergence (De) response from one-year-old ginseng roots exposed to from 30 to 120 days of stratification (Ds).

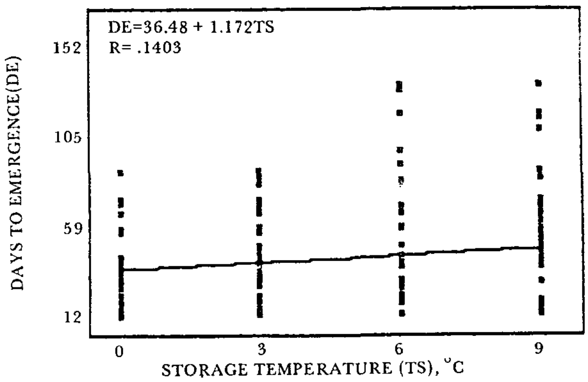

Fig. 2. Days to emergence (De) response from one-year-old ginseng roots stratified at 0, 3, 6 and 9°C storage temperatures (Ts).

The length of the dormant period is a second criterion that may be used for judging the conditions which best satisfy its needs; the shorter the dormant period, the more suitable the conditions.

Days of dormancy (Dd) were calculated for each root that produced a top by adding days in storage to days to emergence (i.e., Dd=Ds+De). The resulting mean Dd's for the combinations of temperature and time in storage were surprisingly constant (Table 3), although an analysis of variance of the data indicated that each of the two factors, Ds and Ts, significantly affected the dormancy period. The data varied around an overall mean of 126.5 days of dormancy. Response was less affected by temperature than by days in storage. Dd decreased from 126 days at 0° storage temperature to 123 days at 3°, then increased to a high of 132 days for roots stored at 9°C. Time of dormancy decreased from 126 days with 45 and 60 days of storage to 119 with 75 days, then increased approximately linearly to 136 days with 120 days of root storage.

These curvilinear (quadratic) responses to the main effects of days in stratification and stratification temperature were the predominate cause of significance in the statistical analysis. They are illustrated in figures 3A and 3B, respectively. The data appear somewhat dispersed about the best fitting quadratic equation line in the graph; however, the correlation coefficients (R=0.591 and 0.302, respectively) both were

Table 3. Days of root-bud dormancy as a function of stratification temperature and days in storage .

Temperature (°C)	Days in Stratification						
	45	60	75	90	105	120	mean[B]
0	125	123	115	122	124	139	126
3	113	124	117	121	128	136	123
6	124	125	116	121	128	134	125
9	143	131	128	130	125	135	132
mean[A]	126	126	119	124	129	136	126.5

[A]LSD (.01) for comparing time means = 4.

[B]LSD (.01) for comparing temperature means = 3.

highly significant.

The data (Table 3 and Figure 3) suggest that the values of Ds and Ts that correspond to minimum days of dormancy were near 75 days in stratification at 3°C storage temperature. The precise minima for the equations in Figure 3A and 3B (as determined by differential calculus) were at 79.5 days and 3.76°C.

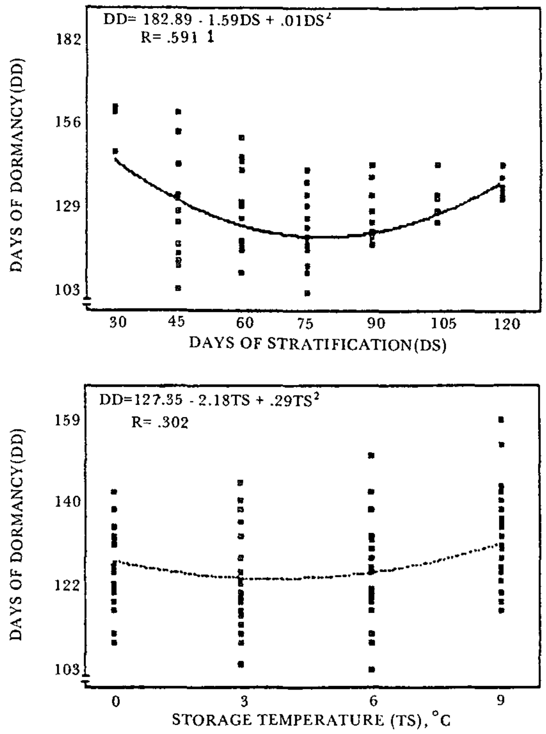

Fig. 3. Days of dormancy (Dd) response of one-year-old ginseng roots to days in stratification (Ds) (A, above) and storage temperature (Ts) (B, below).

Growth Response. While for some purposes the shortest time to emergence or the minimum length of dormancy might be most important in choosing storage conditions, for others the growth response after termination of the dormant period might be paramount.

Roots were weighed at planting and again on October 11, 1982 following emergence, growth and senescence. The percent increase in root weight was calculated as a measure of growth rate and subjected to an analysis of variance.

Days in storage significantly affected the rate of growth to the roots. Growth rate increased with time in storage from 45 days thru 90 days; however, the greatest increase was with 105 days and the second highest with 120 days of stratification (Table 4).

The effect of storage temperature on growth rate was non-significant (Table 4).

If the growth response measured in the experimental material is a true effect of time in stratification, then the results suggest a growth benefit to prolonging the rest period beyond that of complete preparedness for ending dormancy. One-hundred percent emergency was obtained with 75 to 90 days stratification (Table 1), and the shortest period of dormancy was associated with 75 days storage (Table 3), yet the greatest rate of growth occured following 105 days in stratification (Table 4).

Implications of Variability. In any popula-

Table 4. Percent increase in root fresh weight in response to statification temperature and time.

Temperature (°C)	Days in Stratification						
	45	60	75	90	105	120	mean[B]
0	214	174	259	329	468	321	294
3	234	264	291	296	425	367	313
6	181	232	224	245	416	276	262
9	244	296	197	207	370	265	263
mean[A]	218	241	243	269	420	307	

[A]LSD (.01) for comparing time means = 68.

[B]LSD (.01) for comparing temperature means = 56.

tion of organisms, not all the individuals will perform identically. Reasons may be environmental, genetic or both.

In the current study, there was variable response to stratification temperature and time. One of the more interesting responses was percent emergence in which a proportion of root buds broke dormancy with as few as 30 days of chilling; this response was not satisfied in all roots until 75 to 90 days of stratification (Table 1). The question arises as to why 15 percent of roots (6 of 40) were satisfied with 30 days chilling, an additional 40 percent with 15 more days of chilling, etc. When the *added* percentage of roots that emerged with each additional 15 day increment of storage time was plotted against days in storage, the resulting distribution was suggestive of the traditional bellshaped curve of the normal frequency distribution (Fig. 4). If this variability resulted in part from genetic heterogeneity (and it is the author's opinion that a great deal of genetic diversity does exist in *P. quinquefolium*) then selection for and development of strains of ginseng with low chilling requirements, or other desirable characteristic, should be possible.

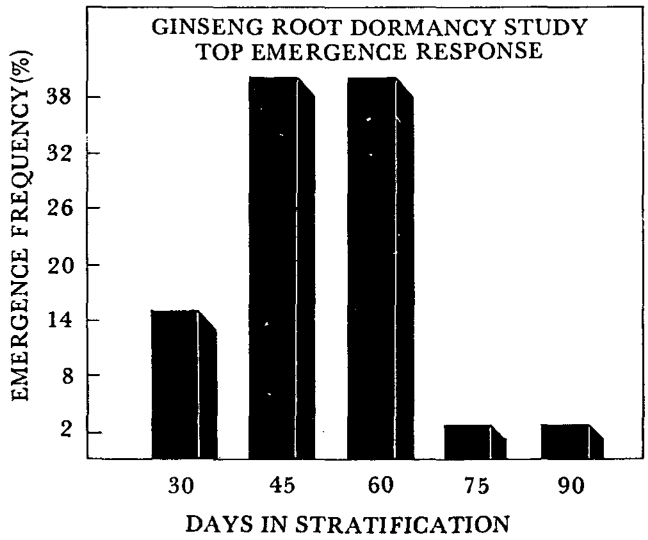

Fig. 4. Emergence frequency response from one-year-old ginseng roots for 30, 45, 60, 75, and 90 days of stratifications.

Cha: This dormancy requirement seems to be quite common for root plants. Is this common to all ginseng species?

Konsler: I suspect it is.

I have not examined any of the other species of that genus but since the plant is limited to the temperate climate which does require or which does have a cold season, it is fairly probable. In my opinion – most of the members of the species would be so dependant on a chilling requirement because many plants are so dependant.

Cha: Are there any attempts as to finding out biochemically why there is dormancy requirement in general?

Konsler: I'm sure there has been a great deal of work on the reason for dormancy requirements. I'm not familiar with the biochemistry that is involved. But I'm sure it has something to do with the growth hormone level within the plant. Perhaps someone else here is more familiar with that phenomenon and could answer better than I.

Cha: Perhaps if someone could find that hormone, one could shorten the dormancy period very drastically.

Konsler: That is very possible. I think you are correct.

미국 인삼근의 저온 휴면 요구도

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미국인삼 1년생근을 재료로 하여 각 온도조건별 (−15, 0, 3, 6, 9, 12 및 15℃)로 120일 이상 온도 처리한 후 온실 조건에 식부하여 성장기간동안 출아 소요일수 및 근중 증가율을 조사하였다.

0℃ 이하와 9℃ 이상에서도 출아가 되지 않았으며 발아기능 온도 범위내에서는 온도에 따른 출아 소요일은 거의 차이가 없었다.

저장기간이 싹의 후면 타파력 및 휴면타파 종료일로부터 발아일(R=91)까지의 기간에 큰 영향을 미쳤다.

100%의 출아를 위해서는 약 1,800시간의 저온 처리가 요구되었다.

720시간의 휴면 타파를 위한 저온 처리를 받은 인삼근의 15%가 근관을 형성하였다.

휴면 타파가 출아에 소요되는 총 시간은 저온 처리의 온도와 관계없이 일정하게 거의 125일(3,000시간)이었다.

이러한 발견은 인삼재배를 위한 온도 조건을 고려한 적지 판정을 하는데 유용하게 이용될 것이다. 이는 개체군에 따라 휴면 타파를 위한 저온처리 충족 요건이 유전적으로 다를 것이라는 사실을 시사해 준다.

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